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Ecological and taxonomic studies of common stipitate Discomycetes of Iowa

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Ecological and taxonomic studies of
common stipitate Discomycetes of Iowa

by

Roger Dean Jensen

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
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PART I

INTRODUCTION

The Discomycetes are a group of sessile or stipitate (stalked) fungi which have cup- or disk-shaped apothecia or some modification of one (e.g., saddle-shaped, bell-shaped, club-shaped, etc.). The apothecia range in size from a few millimeters to 15-20 centimeters in height and are variously colored. In all of the variously shaped apothecia, the asci are borne on the surface or in large cavities and the ascospores are forcibly discharged.

Very few studies concerning Iowa Discomycetes have been published. The last major mycological study to include the common stipitate Discomycetes of Iowa was Seaver's Iowa Discomycetes (1906). The study was based primarily on collections made in eastern Iowa. Since 1906, only a few, very local studies have been published. The limited areas of collection and changes in nomenclature and classification limit the usefulness of these older studies concerning the Iowa stipitate Discomycetes.

Morchella esculenta Pers. ex St. Amans, one of the common stipitate Discomycetes known for its edibility, is avidly collected by many people. Ascocarps of this species and other species of Morchella are often called morels. Despite the popularity of M. esculenta, little is known about the sites where it is collected. No published studies involving soil analyses and vegetational studies of the sites are known.

This study has two objectives: (1) to discuss the common stipitate Discomycetes of Iowa, their habitats, distribution, current nomenclature, and classification and (2) to conduct vegetational studies and soil analyses of sites where M. esculenta occurs.

PART II

LITERATURE REVIEW

General Discussion

The term Discomycetes originally referred to Ascomycetes with a cup- or disk-shaped ascocarp which was called an apothecium. As the term is now applied, it includes all of the Ascomycetes which have a typical or a modified apothecium. The diversity of ascocarp shapes in the Discomycetes has been partly responsible for the diversity of classification systems proposed for this group.

Kimbrough (1970) has presented a historical review of the classification of Discomycetes which covers a period from the late 1700's through the late 1960's. One would expect, as Kimbrough has shown in his review, that classification systems vary from one author to another and change as new information is acquired. A number of classification systems and some of the rationale behind them are discussed in the review. Because of their influence on later classification systems, the more important classification systems, or at least the basis for them, are discussed below as well as some of the recent studies of Discomycetes not reviewed by Kimbrough.

It was not until the late 1700's and early 1800's that significant systematic arrangements of the Discomycetes began to appear. One of the first was Fries' three volume Systema Mycologicum, volumes one, two, and three being published in 1821, 1822, and 1832, respectively. The importance of Fries' work lies in his grouping of the Discomycetes into various taxa (e.g., orders, suborders, families, genera, etc.). Earlier systems lacked these types of groupings. Apothecial shape and consistency were the primary characters used by Fries as the basis for his taxa. One indi-

cation as to the importance of Fries' work is that the Systema Mycologicum was denoted as the beginning of Ascomycete nomenclature by the International Code of Botanical Nomenclature.

Although apothecial shape continued to be used as a taxonomic character in later classification systems, the use of microscopic details (e.g., characteristics of ascospores, asci, etc.) became more common as their taxonomic value became known. Boudier was one of the first to propose a classification system based on dehiscence of the ascus. His system, published in 1907, divided the Discomycetes into two groups--operculates and inoperculates. The asci in the first group, the operculate Discomycetes, have an apical or subapical operculum which is hinged on one side. When the operculum opens, the ascospores are discharged. The inoperculate Discomycetes, which comprise the second group, have asci with thickened apices each of which contains a plug. The ascospores are released through the pore opened by the removal of the plug at the time of dehiscence. Boudier subdivided the two groups on the basis of macroscopic and other microscopic characters. Boudier's system was not generally accepted at the time it was first proposed (Kimbrough, 1970). Ascus dehiscence has been found to correlate with other taxonomic characters and it is now probably used in all Discomycete classification systems.

Seaver (1942, 1951) incorporated the concept of operculate and inoperculate asci into his classification system which he presented in his two volumes of North American Cup Fungi. Unfortunately, he placed more emphasis on the gross morphology of the ascocarp and the substrate upon which it grew. In doing so, unrelated species were, according to current theories of Discomycete classification, grouped into the same taxa. To further

complicate the problem, Seaver followed the American Code of Nomenclature rather than the International Code. Both the American and International Codes follow the principle of priority in naming taxa, but the difference lies in the application of this principle. According to the American Code, the valid binomial (genus species name) for a specimen is the one first published for it. In the International Code, a binomial (for Ascomycetes) is valid if it is listed in Fries' Systema Mycologicum or has been validly published since the publication of the Systema Mycologicum. Despite these shortcomings, Seaver's work was important because it brought together in one place descriptions of most of the species of North American Discomycetes which had been reported up to that time.

In 1932, Nannfeldt published his inoperculate Discomycete studies in which he pointed out the weaknesses of classification systems such as Seaver's. Therefore, Nannfeldt proposed a system in which the main subdivisions were based on the development of the asci and the ascocarp. Families and subfamilies were delimited mainly on the basis of ascospores, asci, and excipulum characteristics. Nannfeldt's developmental studies on inoperculate Discomycetes spurred similar studies which led to a reevaluation of taxa and nomenclature by various workers in the 1940's and 1950's (Kimbrough, 1970).

In 1947, Le Gal published the results of her extensive studies on spore wall formation and ornamentation in operculate Discomycetes. She concluded that the ascospores of the operculate Discomycetes generally are larger, round to elliptical, often ornamented, and nonseptate while those of the inoperculate group are generally smaller, variable in shape, smooth walled, and often septate. She proposed a classification system for oper-

culate Discomycetes based primarily on the ascospore characters. The classification system and taxa proposed by Le Gal are the ones used by most current mycologists in classifying operculate Discomycetes.

The continued trend away from gross morphological characteristics as the primary basis of taxonomic systems was exemplified in Korf's proposed revision (1954) of the classification of operculate Discomycetes. He based his system on the following characters which he listed in order of importance: (1) the ascus, (2) the ascospores, (3) the tissue structure of the apothecium, (4) microchemical reactions, (5) gross morphology, (6) type of sex organs, and (7) conidial states. Much of Korf's work since the 1950's has been concerned with classification and nomenclature. His current classification of the Discomycetes (1973) appears to be based on the same principles which he proposed in 1954 except more emphasis seems to be placed on ascocarp anatomy and microchemical reactions.

Dissing (1966), in his study of the genus Helvella, considered ascocarp anatomy to be the most important taxonomic character in determining species. Spore characters were next in importance. Shape of the ascocarp and other macroscopic characters were considered to have little or no taxonomic value. As a result of his study, Dissing concluded that Paxina, Cyathopodia, Leptopodia, and Macropodia should be considered synonyms of Helvella. Rifai (1968), in his study of the Australasian Pezizales, and Korf (1973) agree with Dissing on the disposition of these genera.

The role of microscopic characteristics in the taxonomy of the operculate Discomycetes has been discussed by Eckblad (1968) and probably expresses the current taxonomic status of these characteristics. Eckblad concluded that, on the family level, the characters that have the highest

taxonomic value are excipular structure, ascus form, ascospore number, ascospore form, and ascospore ornamentation. On the generic level, the important characters are type of hairs, number of oil drops in the ascospores, and ascospore shape. Occasionally, characteristics of paraphyses are of some value. Eckblad considers apothecial form to be of taxonomic value almost only at species level.

Much of the literature concerning Discomycetes is European in origin and is often of a general nature. Relatively few studies have been conducted on North American species. The major studies have been discussed above. Since the stipitate Discomycetes represent only a small portion of the total number of Discomycetes and are represented in several operculate and inoperculate families, very few, if any, studies concerning the stipitate species have been conducted.

Stipitate Discomycetes of Iowa

One of the first stipitate Discomycetes to be described from Iowa (Ellis, 1883) was Holwaya gigantea (Peck) Durand (= Bulgaria ophiobolus Ellis). The species was collected near Decorah by E. W. D. Holway in September, 1882.

In 1884, C. E. Bessey published a preliminary list of fungi found within a twenty mile radius of Ames, Iowa. Stipitate Discomycetes included were Morchella esculenta, Helvella sp., Sclerotinia tuberosa ([Hedw.] Fr.) Fuck. (= Peziza tuberosa Bull.), Sarcoscypha coccinea (Fries) Lambotte (= Peziza coccinea Jacq.), and Bulgaria sp. Descriptions of species and locations of collection sites were not given.

The first major work to include the majority of the species of stipi-

tate Discomycetes of Iowa was Seaver's Discomycetes of Eastern Iowa (1904). Seaver continued and expanded the work, publishing an annotated list in 1905, and in 1906 publishing Iowa Discomycetes which combined the two earlier publications. Descriptions and illustrations, as well as general locations of collection sites, are included in the 1904 and 1906 publications. The majority of the species were collected by Seaver near Iowa City and/or Mt. Pleasant.

In 1910, Wilson reported the occurrence of Sclerotinia tuberosa in Fayette County in northeast Iowa. He also reported, as well as did Gilman and Archer (1929) and Gilman (1932), the occurrence of several other species of the Sclerotiniaceae, but these were the parasitic, asexual stages and not the saprophytic, stipitate, sexual fruiting body stage. The fruiting body of Ciboria pseudotuberosa Rehm (= Sclerotinia pseudotuberosa Rehm), also in the Sclerotiniaceae, was collected by E. W. D. Holway near Decorah, Iowa, and reported by Seaver (1906).

In 1927, Paige published "A list of fleshy fungi from Webster County, Iowa". Among the many species of fungi mentioned are Sarcoscypha coccinea, S. floccosa (Schw.) Cooke, Helvella crispa Fries, H. elastica Bull. ex St. Amans, H. lacunosa Afz. ex Fries, H. sulcata Afz. ex Fries, Morchella conica Pers. ex Pers. (not considered as a species here), M. esculenta, and M. semilibera (DC.) Fries. Locations of collection sites are given for most of the species. As no descriptions are included or herbarium specimens indicated, it can only be assumed that the identifications are correct.

Martin, in his "Notes on Iowa Fungi" (1937, 1939, 1948, 1952, 1954, 1960), mentions the occurrence of fourteen species of stipitate Discomycetes. These are Leotia lubrica Pers., Helvella elastica, Sarcoscypha

occidentalis (Schw.) Cooke (= Plectania occidentalis [Schw.] Seaver), Bulgaria rufa Schw., Helvella atra Holmsk. ex Fries, Leotia chlorocephala Schw., Spathularia flavida Pers. ex Fries, Morchella deliciosa Fries, M. esculenta, M. semilibera (DC.) Fries, M. crassipes Fries (not considered a species here), Verpa conica Swartz ex Persoon, and Monilinia fructicola (Wint.) Honey. As these were common species and most had been reported from Iowa before, Martin's purpose appeared to be to report specimens of unusually large size, to note the rare or repeated appearance of some species, and to note habitats. Species descriptions were usually not given. According to collection data on the herbarium specimens, most of the fungi were collected in the vicinity of Iowa City, Iowa.

Tulk (1942), in his notes on fungi in Henry County, mentions the occurrence of a bright red cup fungus on twigs and humus in the spring and fall. He identified it as Aleuria aurantia (Fries) Fuckel (= Peziza aurantia Pers.) but this is apparently incorrect as A. aurantia is neither bright red nor does it occur on twigs. The bright red color and the occurrence in spring and fall on twigs indicates that the fungus was probably Sarcoscypha coccinea. Tulk also mentions the occurrence of Helvella lacunosa Afz. ex Fries (= H. mitra). Detailed descriptions were not given and herbarium specimens were not indicated.

Seaver's two volume North American Cup Fungi (1942, 1951) included all of the stipitate Discomycetes and other cup fungi that had been collected and reported in North America up to that time. Illustrations and/or detailed descriptions are included. Locations are generalized, usually as ranges (e.g., occurs Iowa to New York), and are, therefore, not useful for the distribution within Iowa. It appears that most of the stipitate Disco-

mycetes Seaver cited as occurring in Iowa were based on his earlier publications of 1904 and 1906.

MATERIALS AND METHODS

Fungi were collected in the years 1973, 1974, and 1975 at various locations and times in Iowa from early April through early November. Table 1 lists the locations of the collection sites. Specimens were collected several different times, each year, at twelve of the sites (denoted in Table 1). The other collections either represent specimens sent to the Iowa State University Botany Department for identification or collections made by graduate students and/or staff members of the Botany Department. Their contributions are gratefully acknowledged.

Voucher specimens were prepared by either preserving the specimens in FAA solution (10 parts ethyl alcohol, 7 parts water, 2 parts formalin, 1 part acetic acid) or air drying them.

Fungal collections in the herbaria or teaching collections of Grace-land College, Luther College, Iowa State University, State University of Iowa, and University of Northern Iowa were examined and collection data recorded. Exsiccata examined were Ellis' 'North American Fungi', Ellis and Everharts' 'North American Fungi', and 'Fungi Columbiana'.

The classification and nomenclatural systems presented by Dennis in his British Ascomycetes (1968) are the ones I have chosen to follow with some modifications. Publications by Dissing (1966), Eckblad (1968), and Korf (1973) contain proposals for some changes, primarily at generic levels in the Helvellaceae, which I have adopted.

Publications by Seaver (1942, 1951) and Dennis (1968) were used for the identification of most of the species collected. For the identification of the species of Rutstroemia, White's monograph (1941) was used.

Table 1. Location of collection sites in Iowa

County	Township name	Township location		Site
Allamakee ^a	Creek	T-97N	R-4W	Yellow River State Forest
Boone	Cass	T-82N	R-26W	4-H Camp
Boone ^a	Worth	T-83N	R-26W	Ledges State Park
Boone ^a	Yell	T-84N	R-27W	Holst State Forest
Clayton	Lodomillo	T-91N	R-5W	Bixby State Park
Decatur ^a	Hamilton	T-67N	R-25W	Nine Eagles State Park
Delaware	Richland	T-90N	R-6W	Backbone State Park
Des Moines	Tama	T-70N	R-2W	Section 19, private woods
Dickinson	Okoboji	T-98N	R-37W	Section 10, private woods
Dubuque ^a	Liberty	T-90N	R-2W	White Pine Hollow State Preserve
Emmet	Estherville	T-99N	R-34W	Fort Defiance State Park
Fremont ^a	Washington	T-68N	R-42W	Waubonsie State Park
Guthrie	Dodge	T-81N	R-31W	Section 31, private woods
Guthrie	Dodge	T-81N	R-31W	Springbrook State Park
Hamilton	Fremont	T-89N	R-26W	Section 2, private woods
Hardin	Clay	T-88N	R-19W	Section 6, Hardin Co. Cons. Bd. Woods
Hardin	Etna	T-89N	R-19W	Section 32, Hardin Co. Cons. Bd. Woods
Harrison	Little Sioux	T-81N	R-45W	Section 16, Iowa Game Management Area
Harrison	Washington	T-78N	R-41W	Section 32, private woods

^aSites where collections were made each year, several times a year.

Table 1. (Continued)

County	Township name	Township location		Site
Iowa	Washington	T-81N	R-10W	Section 13, private woods
Kossuth ^a	Cresco	T-95N	R-29W	A.A. Call State Park
Lee ^a	Harrison	T-68N	R-7W	Shimek State Forest
Linn	Putnam	T-82N	R-6W	Palisades-Kepler State Park
Lucas ^a	Jackson	T-72N	R-23W	Stevens State Forest
Marshall	Bangor	T-85N	R-19W	Section 16, private woods
Polk	Crocker	T-80N	R-24W	NW of Deere plant 1 mile, along Hwy. 415
Polk	Jefferson	T-81N	R-25W	Section 29, Jester Park
Pottawattamie ^a	Hazel Dell	T-76N	R-43W	Section 36, private woods
Ringgold	Riley	T-67N	R-28W	Section 28, private woods
Story	Milford	T-84N	R-23W	Section 6, private woods
Story ^a	Franklin	T-84N	R-24W	Lynn Fuhrer Woods
Van Buren	Bonaparte	T-68N	R-8W	Section 24, private woods
Van Buren	Des Moines	T-68N	R-10W	Lacey-Keosauqua State Park
Webster	Otho	T-88N	R-28W	Dolliver Memorial State Park
Webster ^a	Otho	T-88N	R-28W	Woodman's Hollow State Preserve
Winneshiek	Canoe	T-99N	R-8W	Malanaphy Springs
Woodbury	Sioux City	T-89N	R-48W	Stone State Park

The other publications used for species identification are noted above.

For the purposes of this study, the common stipitate Discomycetes of Iowa, both operculates and inoperculates, have been defined as those species that have apothecia larger than 2 millimeters in diameter and obvious stalks. Most of the common stipitate species found in Iowa are in six families: Morchellaceae, Sarcoscyphaceae, Geoglossaceae, Sclerotiniaceae, Helvellaceae, and Helotiaceae. Keys, based on microscopic and macroscopic characters, have been constructed for the families, genera, and species of stipitate Discomycetes in Iowa. The descriptions of taxa were adapted, with some modifications, from Seaver (1942, 1951), Dennis (1968), and Dissing (1966). The months listed in parentheses following each species description indicate the months during which that species was collected or present in the field. Only specimens collected during this study or those that I have seen in fresh field collections are described and discussed. Genera and species not described and discussed, except for distribution, are listed in parentheses in the keys.

The distribution given for each species is based on collections made during this study, on collections made by Field Mycology classes held at Iowa State University or at Iowa Lakeside Laboratory, and on data obtained from herbarium or teaching specimens. For each county in which a specimen of a particular species has been collected, the county is listed followed by one or more abbreviations and dates. The abbreviations indicate where the preserved specimens can be found and the dates indicate the year or years of collection. Years listed in parentheses indicate specimens which were not kept or could not be located. The following abbreviations are used:

GC = Graceland College, Lamoni, Iowa

ISU = Iowa State University, Ames, Iowa

LC = Luther College, Decorah, Iowa

RDJ = Collections made during this study, located at ISU

UI = State University of Iowa, Iowa City, Iowa

UNI = University of Northern Iowa, Cedar Falls, Iowa

Distribution maps were prepared for each of the described species.

Dots (●) on the maps indicate specimens collected during this study; circles (○) indicate a herbarium or teaching collection specimen or those specimens which were denoted by dates in parentheses.

RESULTS AND DISCUSSION

Key to the Families of Stipitate Discomycetes in Iowa

1. Asci operculate; apothecia brightly colored, usually 1 cm in diameter or larger (apothecia of Urnula not brightly colored)..... 2
2. Apothecia growing on woody substrate; thick-walled asci with subapical ring below the nearly terminal operculum..... Sarcoscyphaceae
2. Apothecia not growing on woody substrate; asci not as above, operculum terminal..... 3
3. Hymenium usually pitted; ascospores elliptical, without internal oil drops, external granules may adhere to ends of ascospores..... Morchellaceae
3. Hymenium usually smooth or convoluted, not truly pitted; ascospores elliptical to fusiform, with large internal oil drops..... Helvellaceae
1. Asci inoperculate; apothecia usually not brightly colored; apothecia less than 1 cm in diameter..... 4
4. Apothecia club-shaped, spathulate or capitate; usually on the ground..... Geoglossaceae
4. Apothecia cup-shaped or discoid; usually on living or dead plant tissue..... 5
5. Apothecia arising from sclerotia or stromatized portions of host tissue..... Sclerotiniaceae
5. Apothecia not arising from sclerotia..... Helotiaceae

Sarcoscyphaceae

Apothecia cup-shaped, bright colored or brown to blackish, usually tough, excipulum tomentose or hairy, composed of filamentous or long-celled hyphae; growing on buried or partially buried sticks or wood; stipitate, stalk variable in length, occasionally lacking, the length determined by the degree to which the woody substrate is buried in the soil, stalk slender or thick, even or furrowed; asci clavate to cylindrical, rather thick walled, a thickened apical ring present below the subapical or terminal operculum, not blued by iodine, 8-spored; ascospores elliptical or globose, hyaline, one celled.

Key to genera and species in Iowa

1. Hymenium red, excipulum whitish..... Sarcoscypha.. 2
 2. Apothecia large, 3-4 cm in diameter; fruiting in spring and occasionally late fall..... S. coccinea
 2. Apothecia smaller, 1-2 cm in diameter; fruiting in summer..... 3
 3. Apothecial hairs very conspicuous, long and bristly; apothecia goblet-shaped..... S. floccosa
 3. Apothecial hairs inconspicuous, consisting of delicate tomentum; apothecia shallow..... S. occidentalis
1. Hymenium brown or black, excipulum dark colored..... 4
 4. Hymenium and excipulum black; apothecia 2-4 cm in diameter, not rubbery in texture; fruiting in spring.....Urnula craterium
 4. Hymenium brownish; excipulum of apothecia darker, blackish-brown; apothecia having a rubbery texture when fresh; fruiting in summer..... Bulgaria rufa

Sarcoscypha (Fries) Boudier

Apothecia stipitate to substipitate, subglobose then cup-shaped with a more or less incurved margin, excipulum downy or hairy, hairs usually hyaline; hymenium bright colored, usually reddish; asci 8-spored, ascospores elliptical or oblong, smooth, hyaline, one celled; paraphyses filiform.

Sarcoscypha coccinea (Fries) Lambotte (Figure 3)

Apothecium a deep cup, large, 2-6 cm in diameter, short stalked or rarely sessile; stalk stout, 4-5 mm thick and of variable length, often 2-3 cm long, margin of cup incurved, hymenium scarlet, fading when dry, excipulum nearly white and more or less floccose with matted hyaline hairs; asci long, cylindric, gradually tapering to a stem-like base, reaching a length of 400-500 μm and a diameter 12-14(-16) μm ; ascospores usually uniseriate, hyaline, elliptic-cylindric, with rounded ends, 26-40 x 10-12(-14) μm ; often with two large oil drops and/or with small oil droplets cohering in two clusters, one cluster at each end of the ascospore; paraphyses slender, slightly enlarged above, with numerous red granules.

On buried or partially buried sticks or wood (common on Tilia spp.); early spring (March-May) and occasionally late fall (October-November).

Fairly common.

Distribution (Figure 1)

Black Hawk: UNI 1960; Boone: RDJ 1974; Clayton: RDJ 1975; Delaware: RDJ 1974; Des Moines: RDJ 1975; Dubuque: RDJ 1974, 1975; Fayette: RDJ 1974; Floyd: UI 1912; Fremont: RDJ 1974; Guthrie: RDJ 1974; Hamilton: RDJ 1975; Hardin: RDJ 1975; Iowa: UI 1946,

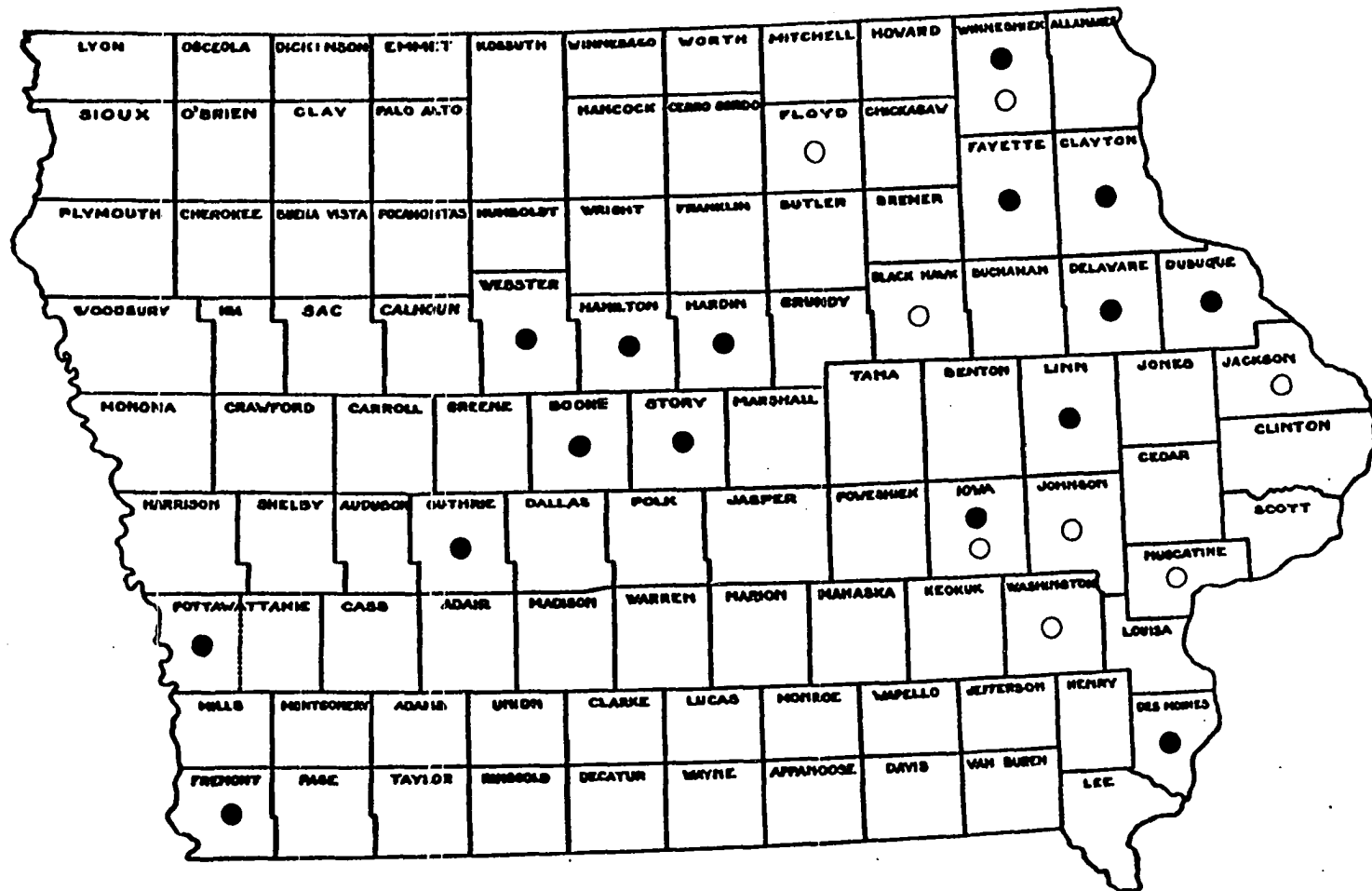


Figure 1. Distribution of Sarcoscypha coccinea (Fries) Lambotte in Iowa

RDJ 1974; Jackson: UI 1961; Johnson: UI 1905, 1923, 1926, 1935, 1946, 1963; Linn: RDJ 1974; Muscatine: UI 1923; Pottawattamie: RDJ 1974; Story: RDJ 1974; Washington: UI 1939; Webster: RDJ 1974; Winneshiek: ISU 1879, LC 1900, RDJ 1975.

Sarcoscypha floccosa (Schw.) Cooke (Figure 4)

Apothecia gregarious or occasionally clustered; goblet shaped with the margin usually strongly incurved especially in young plants, cup portion of apothecia reaching a diameter of 5-8 mm and a depth of 1 cm, excipulum clothed with very long, rigid, hyaline hairs which give the cups a very shaggy appearance; hairs about 15-18 μ m in diameter at the base, tapering to a bristle-like apex, reaching a length of more than 1 mm, separate, thick walled; stalk slender, gradually expanding and merging with the cup above, length variable; asci cylindric or subcylindric, rather abruptly narrowed into a long stem-like base, reaching a length, excluding the base, of 300-325 μ m and a diameter of 20 μ m at the apex; ascospores uniseriate or with the ends partially overlapping, ellipsoid, with ends rather strongly narrowed, smooth, hyaline or slightly yellowish, 20-35 x 15-17 μ m; paraphyses slender, slightly enlarged above, reaching a diameter of 3 μ m at the apices.

On buried or partially buried sticks or wood in wooded areas, often occurring on Carya ovata (Mill.) Koch; summer (June-August). Fairly common.

Distribution (Figure 2) Allamakee: RDJ 1973, 1974; Appanoose: UI 1902; Boone: ISU 1971, RDJ 1975; Dickinson: ISU (1964), UI 1926; Dubuque: RDJ 1973; Emmet: ISU (1968), (1970), 1972, RDJ 1974; Johnson: UI 1903, 1924; Marshall: RDJ 1974; Story: RDJ 1974; Webster: ISU (1962),

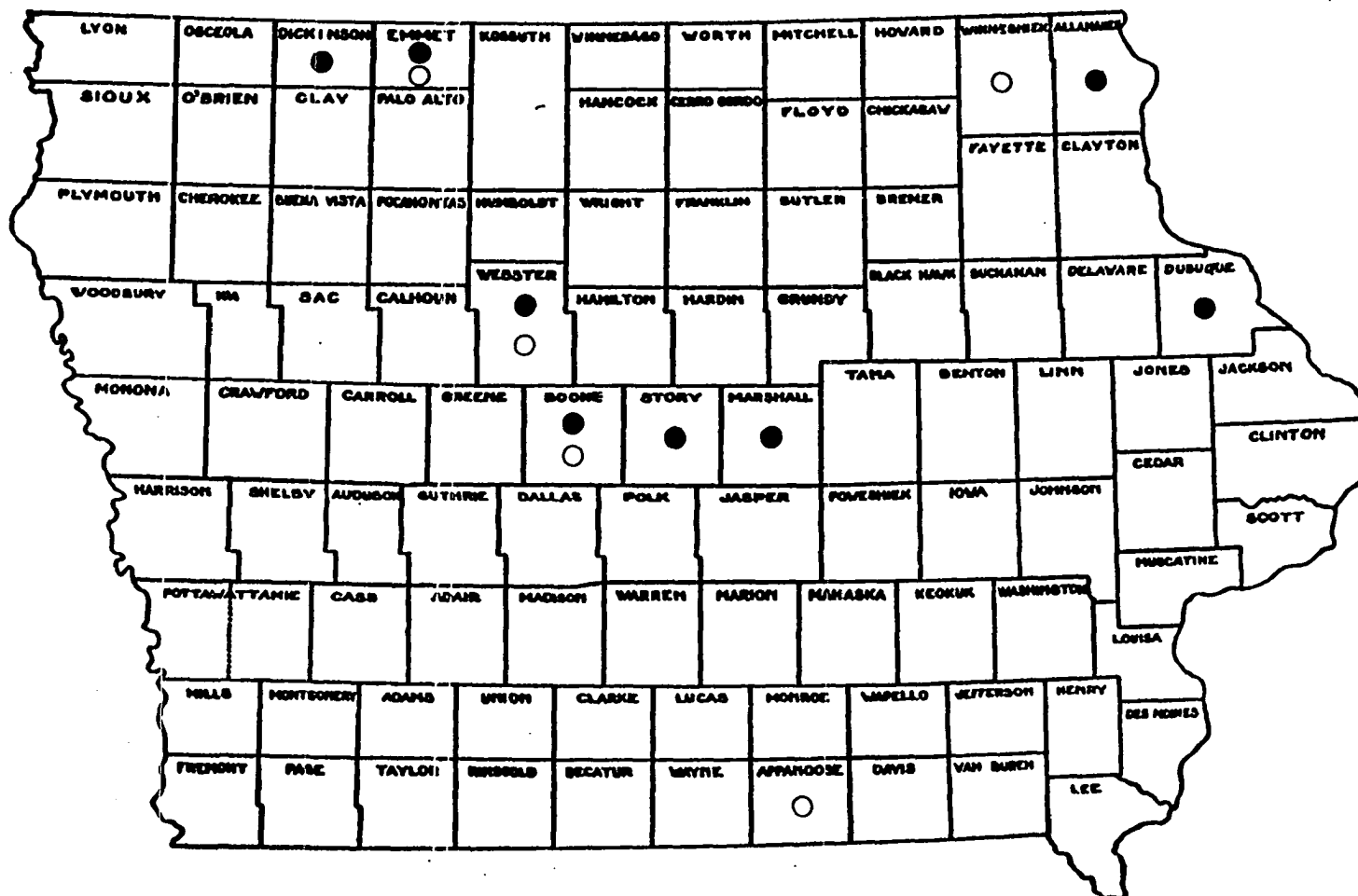


Figure 2. Distribution of Sarcoscypha floccosa (Schw.) Cooke in Iowa



Figure 3. Sarcoscypha coccinea

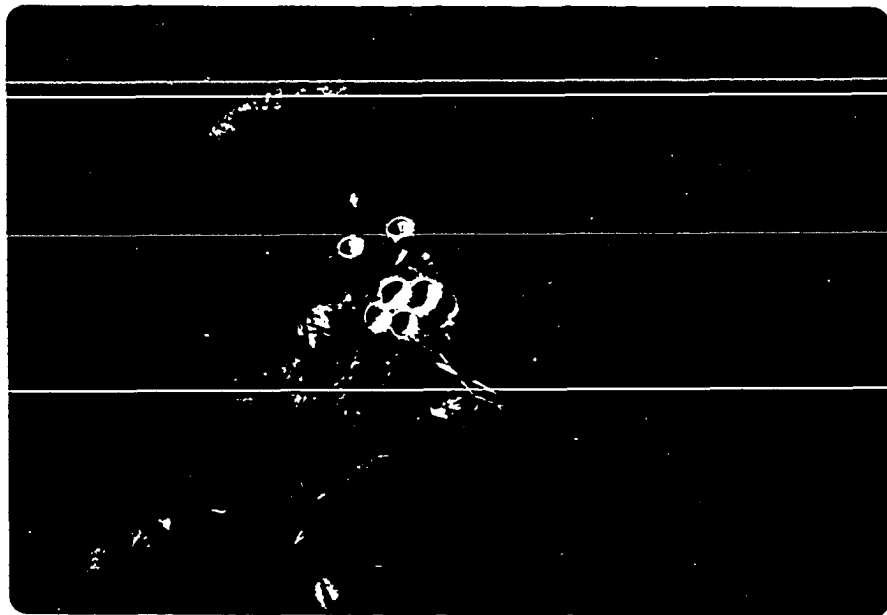


Figure 4. Sarcoscypha floccosa

RDJ:1974; Winneshiek: ISU 1882.

Sarcoscypha occidentalis (Schw.) Cooke (Figure 7)

Apothecia gregarious or in clusters; shallow cup-shaped to discoid, excipulum whitish, reaching a diameter of 1 cm (rarely 2-3 cm), hymenium usually concave, bright red, almost scarlet; stalk variable in length often reaching a length of 2-3 cm and a diameter of 2 mm; asci cylindric or subcylindric, reaching a diameter of 15-18 μ m at the apex, tapering below into a long stem-like base; ascospores uniseriate, parallel with the ascus or oblique, ellipsoid, usually with two oil drops, one in either end are often surrounded with smaller oil drops and granules, hyaline or slightly yellowish, 20-22 x 10-12 μ m, paraphyses slender, slightly thickened above, reaching a diameter of 3-4 μ m at their apices.

On buried or partially buried sticks or wood in moist areas, often occurring on Carya ovata; late spring to early fall (late May-October), Fairly common.

Distribution (Figure 5) Allamakee: RDJ 1973, 1974; Boone: RDJ 1973, 1974 (1975); Clayton: RDJ 1973; Des Moines: RDJ 1974; Dickinson: ISU (1964), (1972), UI 1926; Dubuque: RDJ 1973; (1974); Emmet: ISU (1962), (1968), 1970, (1972), RDJ 1973, 1974; Fremont: RDJ 1973; Hardin: RDJ 1975; Harrison: RDJ 1973; Henry: RDJ 1973; Iowa: UI 1927, RDJ 1973, 1974; Johnson: UI 1904, 1938, 1946; Marshall: RDJ 1974; Muscatine: RDJ 1973; Polk: RDJ 1975; Pottawattamie: RDJ 1973; Ringgold: RDJ 1973; Story: RDJ 1974; Van Buren: RDJ 1973; Webster: ISU (1962), RDJ 1973, (1974); Winneshiek: RDJ 1974.

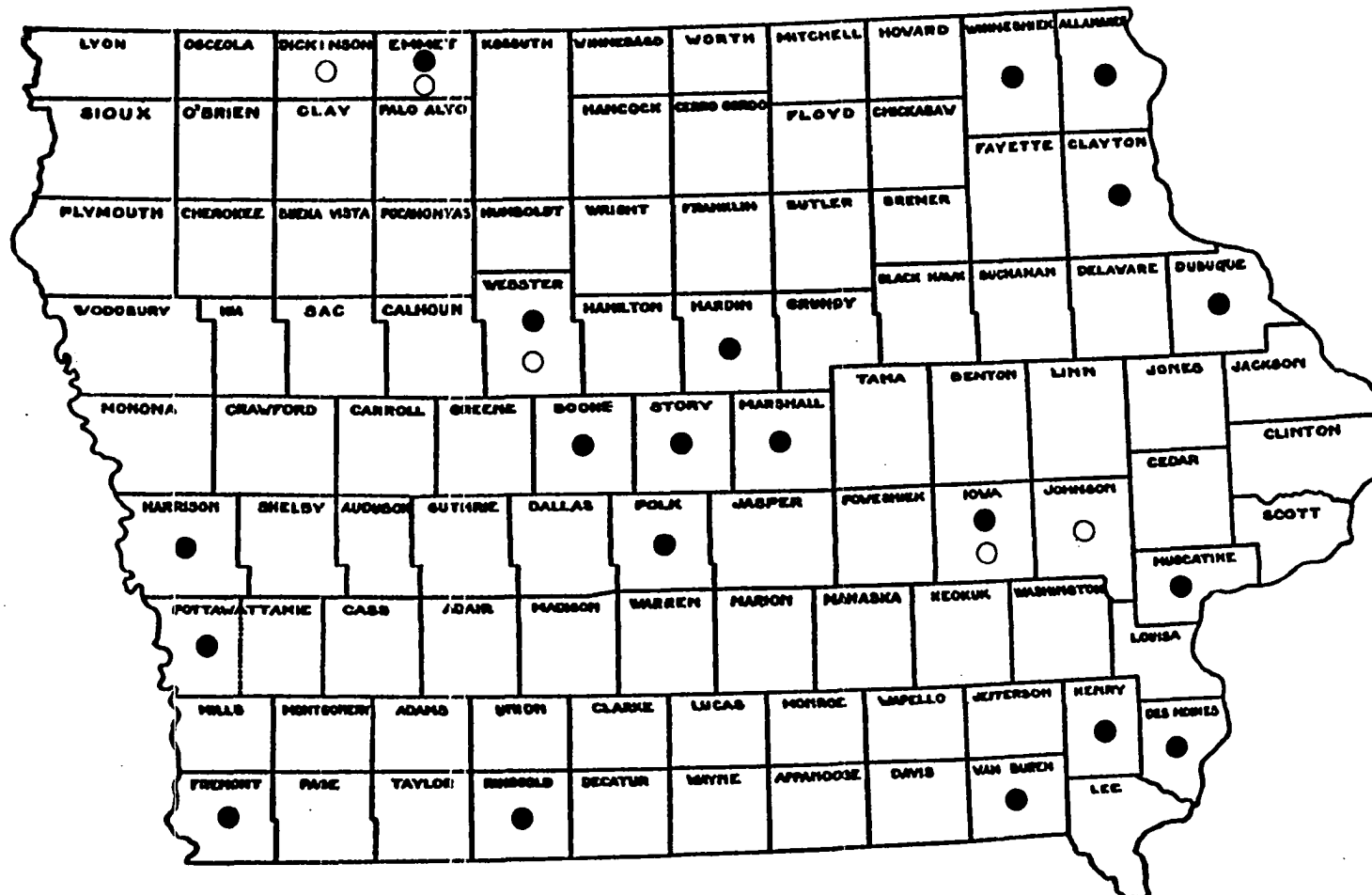


Figure 5. Distribution of Sarcoscypha occidentalis (Schw.) Cooke in Iowa

Urnula craterium (Schw.) Fries (Figure 8)

Apothecia at first closed above, finally opening by a star-shaped aperture which leaves the margin notched and infolded, excipulum black or brownish-black and clothed with hairs forming a dense tomentum; apothecia reaching a diameter of 3-4(-5) cm and a depth of 4-6(-7) cm, the substance tough and leathery, hymenium brownish-black, a little paler than the excipulum; stalk reaching a length of 3-4 cm and a diameter of 5-8 mm, even or very slightly lacunose near the base, black or brownish-black and attached to the substratum by a dense mass of black mycelium, gradually expanding upward and merging with the cup above; hairs variable in length, thin walled, sparingly septate, flexuous, about 10 μ m in diameter and of nearly uniform thickness throughout their length; asci cylindric above, tapering below into a long stem-like base, reaching a length of 600 μ m and a diameter of 15-17 μ m; ascospores uniseriate, broad-ellipsoid, smooth, hyaline, 25-35 x 12-14 μ m; paraphyses threadlike, slightly enlarged above, pale brown.

On buried or partially buried sticks or wood, usually Quercus spp.; early spring (April-May). Common.

Distribution (Figure 6) Boone: RDJ 1974, 1975; Clayton: RDJ 1975; Decatur: RDJ 1974; Dubuque: UI 1908, RDJ 1974, (1975); Guthrie: RDJ 1974; Hardin: RDJ 1975; Iowa: UI 1924, RDJ 1974, (1975); Lee: RDJ 1975; Linn: UI 1933; Lucas: RDJ 1975; Johnson: UI 1924, 1935; Pottawattamie: RDJ 1975; Story: ISU 1899, RDJ 1974; Van Buren: RDJ 1975; Winne-shiek: ISU 1882, LC 1889, RDJ 1975.

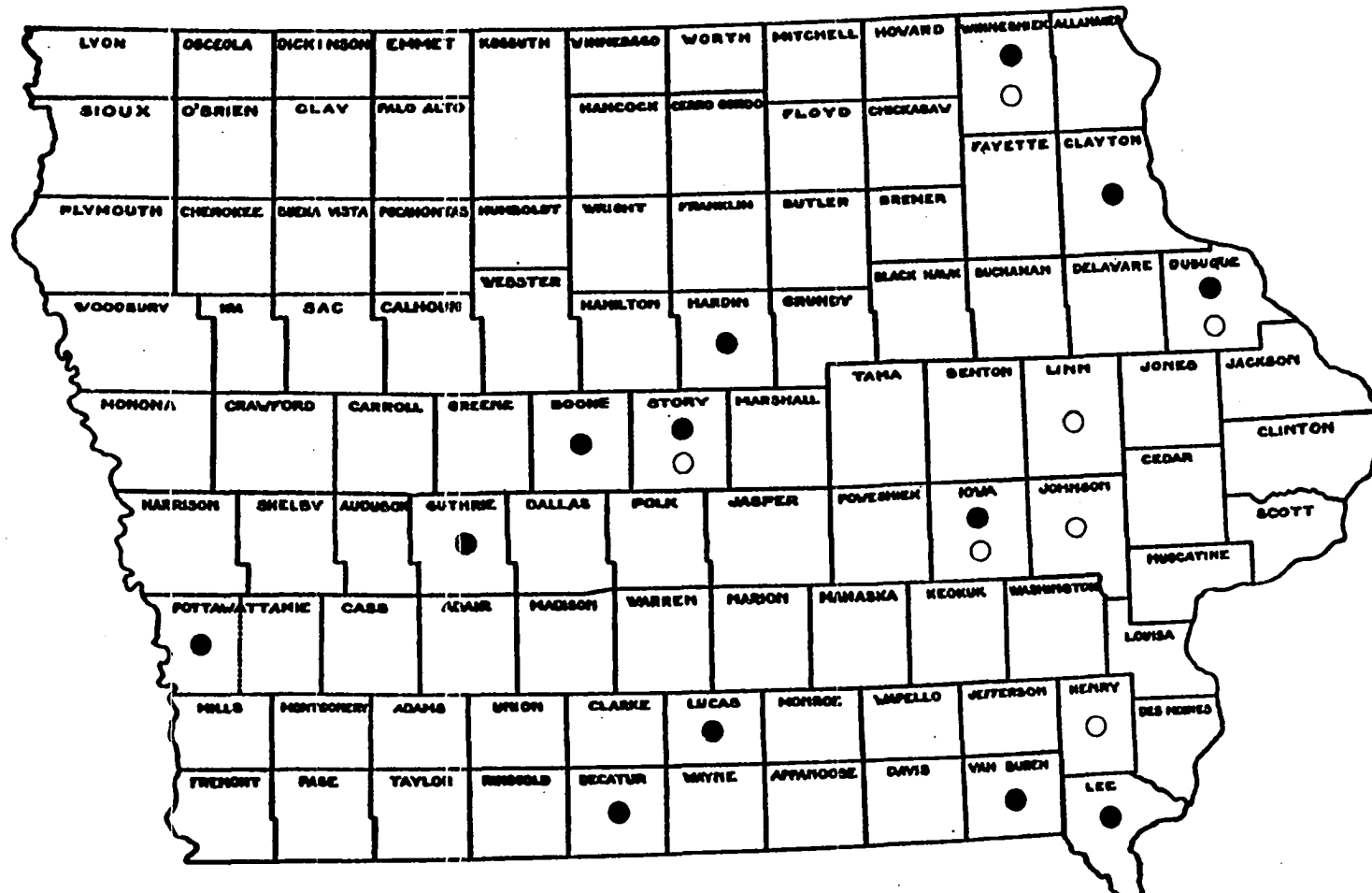


Figure 6. Distribution of Urnula craterium (Schw.) Fries in Iowa

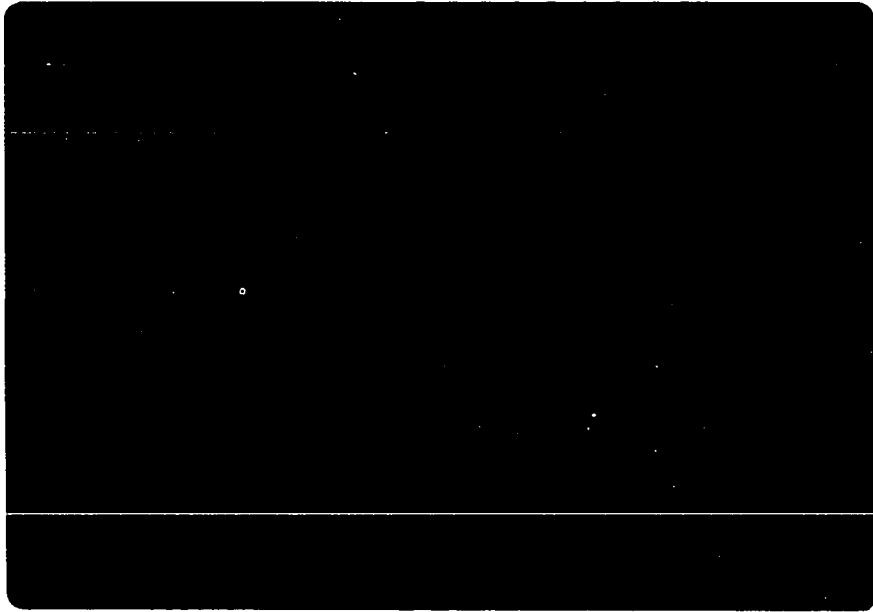


Figure 7. Sarcoscypha occidentalis

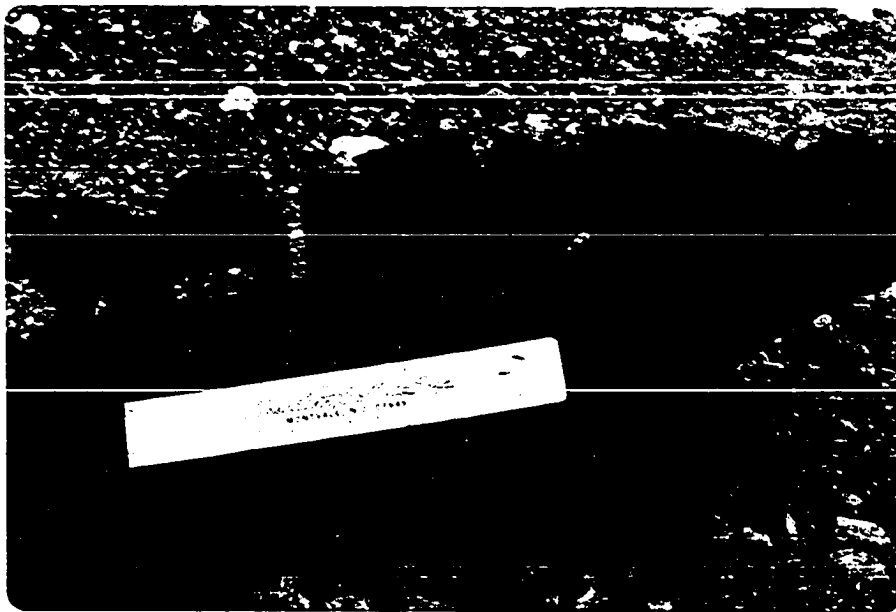


Figure 8. Urnula craterium

Bulgaria rufa Schw. (Figure 11)

Apothecia gregarious or clustered, short stipitate or occasionally sessile, attaining a diameter of 2-3 cm, shallow cup-shaped, with the margin incurved; excipulum blackish-brown, tough and covered over with clusters of hairs, internally with a gelatinous layer several millimeters thick, giving the fresh plants a rubbery consistency, on drying becoming leathery and strongly wrinkled; hymenium slightly concave, pale-reddish or reddish-brown; stalk reaching a length of 1 cm or more and a diameter of 4-5 mm, attached below by means of a dense mass of black mycelium; hairs blackish-brown; asci cylindric above, gradually tapering below into a long stem-like base, reaching a length of 275-300 μm and a diameter of 12-14 μm ; ascospores uniseriate, ellipsoid, with ends strongly narrowed, hyaline, granular within, 18-20 x 9-12 μm ; paraphyses threadlike, scarcely enlarged above.

On buried or partially buried sticks or wood; summer (June-September).

Common.

Distribution (Figure 9) Allamakee: RDJ 1973, (1974); Boone: ISU 1971, RDJ 1973; Clayton: RDJ 1974; Decatur: RDJ 1973; Delaware: RDJ 1973; Des Moines: RDJ 1974; Dubuque: RDJ 1973; Henry: UI 1905; Iowa: UI 1923, RDJ 1973, 1974; Johnson: UI 1923, 1926, 1937, 1938; Kossuth: RDJ 1974; Lee: RDJ 1973; Muscatine: RDJ 1973; Story: RDJ 1973; Webster: RDJ 1973, (1974).

Morchellaceae

Apothecia shape variable, ranging from a nearly sessile, discoid form to stalked forms with smooth or pitted, cap-like hymenial areas; ectal

excipulum of textura angularis to textura prismatica; asci cylindrical, usually 8-spored (2-spored in one species); ascospores smooth walled, one celled, usually hyaline, without prominent internal oil drops but bearing on each end of the ascospores a number of small external granules which are especially evident in young ascospores.

Key to genera and species in Iowa

1. Apothecium having a cap-like hymenial area with pits and/or ridges; hymenial area somewhat spherical or conical in outline, at the apex of a long stalk..... 2
2. The hymenial area attached at its base to the stalk or else free for half of its length; 8-spored usually..... Morchella.. 3
3. Hymenial area attached for half of its length, conical, 2-3 cm in length..... M. semilibera
3. Hymenial area completely attached to the stalk..... 4
4. Hymenial area large, 4-5 cm in diameter, 7-9 cm in length, shape variable, subglobose to subconical, yellowish-brown to grayish..... M. esculenta
4. Hymenial area smaller, 1-2 cm in diameter, 2-3 cm in length, grayish; appearing before M. esculenta M. deliciosa
2. Hymenial area free from stalk except at the stalk apex.. Verpa.. 5
5. Asci 2-spored usually; hymenial surface furrowed, appearing pitted..... V. bohemica
5. Asci 8-spored; hymenial surface smooth or slightly furrowed..... V. conica

1. Apothecium not as above; flattened cup, hymenial surface often
furrowed appearing reticulate; stalk short (less than 1 cm).....
..... Disciotis venosa

Morchella St. Amans

The cap-like hymenial area conical to subglobose, but very variable in shape and size, the margin closely adnate or free (in one species) from the hollow, whitish stalk at the base; surface of the hymenial area pitted, the rounded or elongated depressions entirely lined within by grayish or yellowish to brownish hymenium; paler, sterile irregularly anastomosing ridges separate the pits; asci 8-spored; ascospores smooth, yellowish or cream colored in mass.

Morchella semilibera (DC.) Fries (Figure 12)

Cap-like hymenial area bell-shaped or subconic, reaching a length of 2-3 cm and a diameter of 1.5-2 cm, free from the stalk for about half of its length; pits irregularly rounded or elongated, reaching a diameter of 5-10 mm, yellowish to brownish within; longitudinal walls of the pits more developed, when young lighter than the interior of the pits, darkening and becoming more prominent with age; stalk at first short, finally reaching a length of 8-10 cm and a diameter of 2-3 cm at the base, tapering upwards to about half of the diameter of the base, often irregularly furrowed at the base, hollow, brittle, whitish or yellowish, scurfy; asci cylindric reaching a length of 250-300 μm and a diameter of 20-25 μm ; ascospores uniseriate, elliptical, 22-26 x 12-16 μm , hyaline, cream colored in mass; paraphyses enlarged upwards, hyaline or slightly colored.

In moist woods, on the ground. Spring (late April-May) about the

same time as M. esculenta. Fairly common.

Distribution (Figure 10) Boone: ISU 1972, 1973, RDJ 1974; Black Hawk: UNI 1942; Decatur: GC 1972; Delaware: RDJ (1973); Des Moines: RDJ 1975; Dubuque: UI 1905, RDJ 1974; Fremont: RDJ 1975; Guthrie: RDJ (1973); Hardin: RDJ 1975; Jasper: UI (no date); Johnson: 1898, 1931, 1943, 1955; Lucas: RDJ 1975; Story: ISU 1902, RDJ 1975; Van Buren: RDJ 1975; Webster: RDJ 1974.

Morchella esculenta Persoon ex St. Amans (Figure 17)

Shape of hymenial area variable, usually subglobose or elongated, occasionally tapering to an obtuse point at the apex, size variable, often 4-5 cm in diameter and 7-9 cm in length; pits rounded, irregular or occasionally elongated, usually grayish at first, becoming yellowish-brown, darker with age or on drying, 5 mm to 10 mm in diameter; ridges irregularly anastomosing, not longitudinally disposed, about 1 mm thick and lighter colored than the interior of the pits; stalk hollow, stout, but the diameter not usually exceeding two-thirds the diameter of the hymenial area, usually a little enlarged at the base, even or irregularly furrowed, whitish to yellowish, lighter than the hymenial area, minutely scurfy; asci 8-spored, cylindric, reaching a length of 200-300 μ m and a diameter of 18-20 μ m; ascospores uniseriate, broadly elliptical, hyaline, yellowish in mass, (16-)20-24 μ m; paraphyses enlarged above reaching a diameter of 15 μ m, faintly colored.

On ground in woods and open places; spring (late April, May). Common.

A large form of M. esculenta appearing towards the end of the fruiting season and usually having a larger stalk, is considered by some authorities,

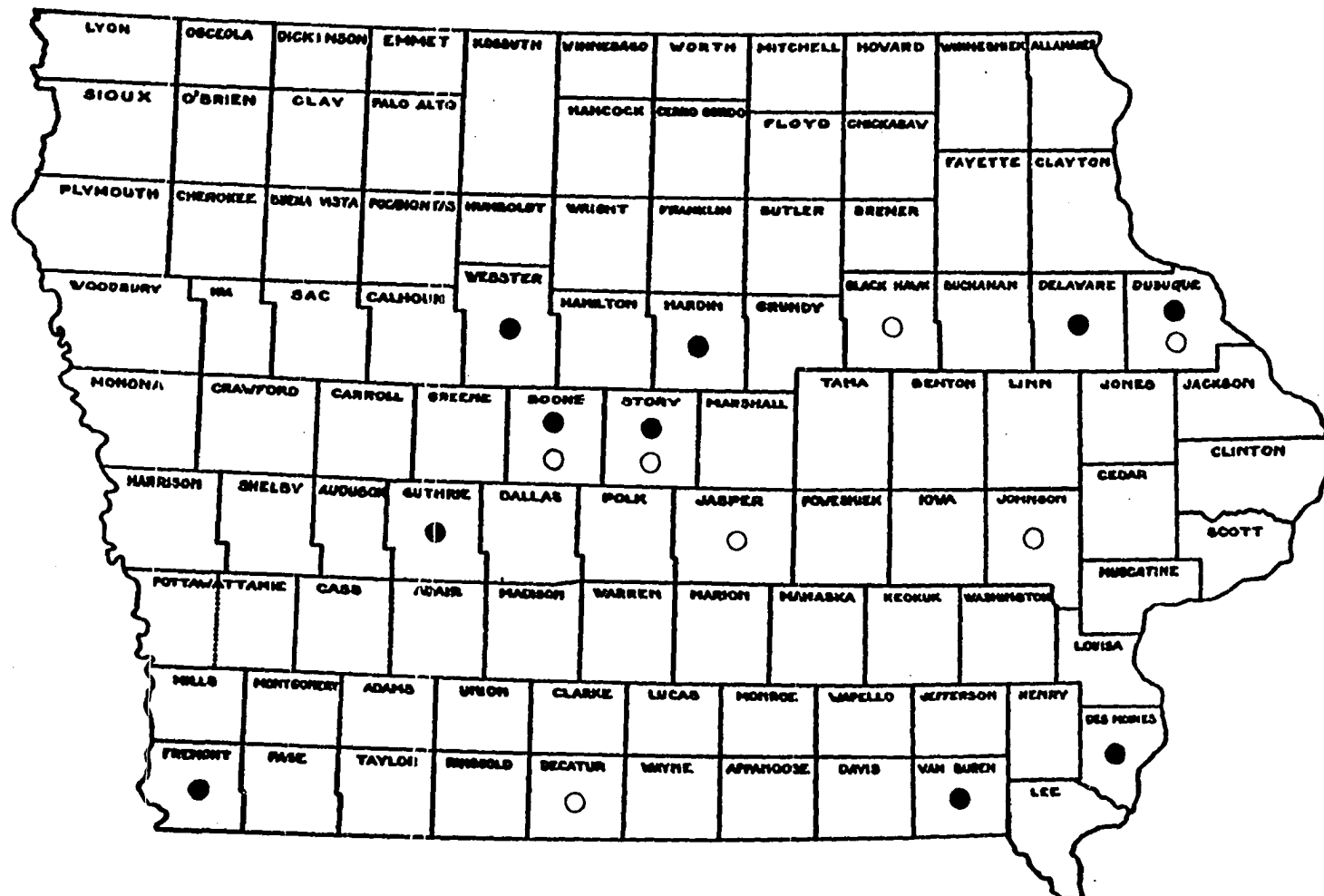


Figure 10. Distribution of *Morchella semilibera* (DC.) Fries in Iowa

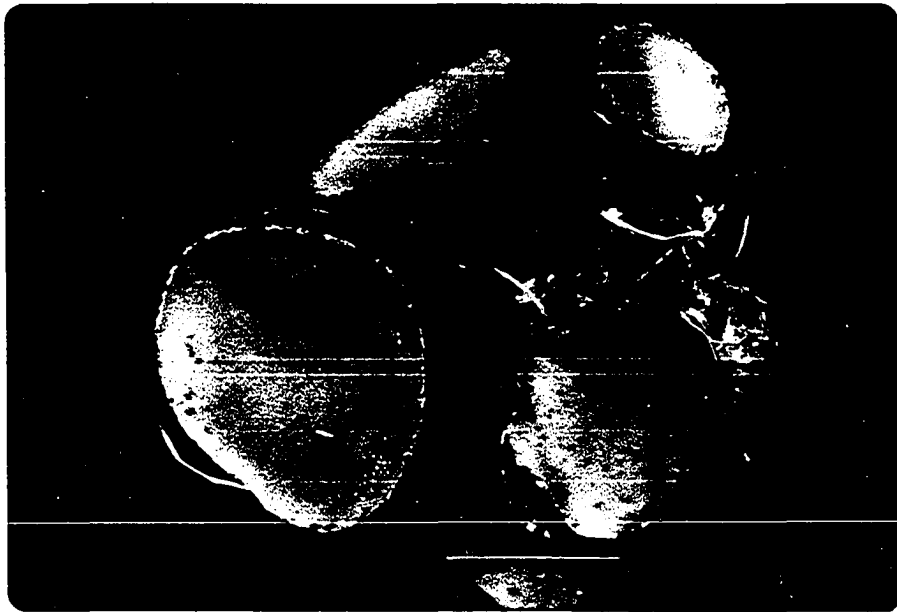


Figure 11. Bulgaria rufa

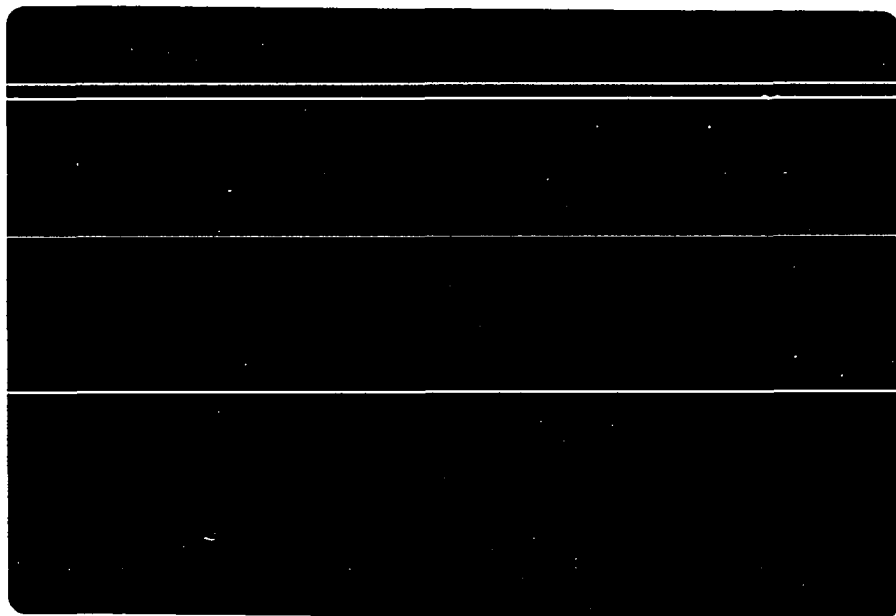


Figure 12. Verpa bohemica (left), Morchella semilibera (right)

on the basis of the stalk and lateness, to be a separate species. I do not consider it to be a separate species as the size and shape of the asci and ascospores do not differ significantly. Furthermore, field studies by Groves and Hoare (1953) indicate that M. crassipes (Fries) is a late season stage of M. esculenta.

Distribution (Figure 13) Allamakee: RDJ 1974; Boone: RDJ 1974, (1975); Clayton: RDJ 1975; Decatur: RDJ 1974; Dubuque: RDJ 1974; Emmet: RDJ 1975; Fremont: RDJ 1974, (1975); Guthrie: RDJ 1974; Hardin: RDJ 1975; Harrison: RDJ 1975; Iowa: UI 1925; Johnson: UI 1925; Johnson: UI 1933 (as M. conica); Johnson: UI 1931, 1938, 1943 (as M. crassipes); Kosuth: RDJ 1975; Lucas: RDJ 1975; Muscatine: UI 1911; Pottawattamie: RDJ 1974; Story: ISU 1902 (as M. angusticeps), RDJ 1974; Webster: RDJ 1974, 1975; Woodbury: RDJ 1975; Winneshiek: LC 1889, RDJ 1975.

Morchella deliciosa Fries (Figure 17)

Cap-like hymenial area elongated to somewhat conical, reaching a length of 2-3 cm and a diameter of 1-2 cm; pits usually elongated, grayish to blackish within, ridges inclined to be longitudinally disposed, about 1 mm thick, irregularly anastomosing, much lighter than the interior of the pits, whitish; stem one-half to two-thirds as thick as the base of the hymenial area, occasionally enlarged at the base and irregularly lacunose, lighter than the hymenial area, whitish or yellowish; asci cylindrical, reaching a length of about 200 μ m and a diameter of 12-15 μ m; ascospores uniseriate, ellipsoid, hyaline, yellowish in mass, 20 x 10 μ m; paraphyses somewhat enlarged at their apices and slightly colored.

On ground in woods, or in grassy places near edge of woods. Usually

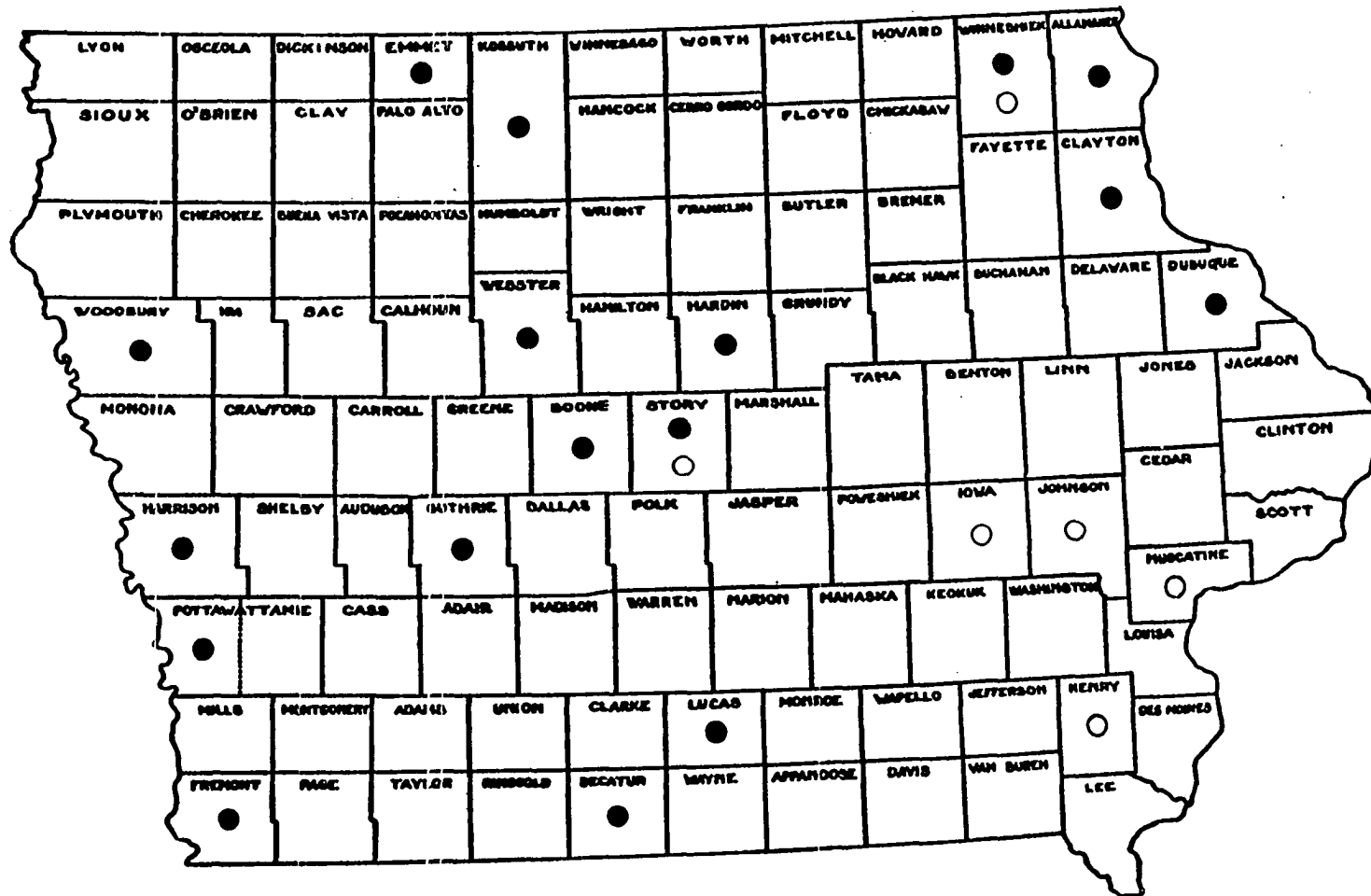


Figure 13. Distribution of Morchella esculenta Persoon ex St. Amans in Iowa

appearing about 1-2 weeks before M. esculenta; spring (late April, early May). Fairly common.

Groves and Hoare (1953) consider this species as an early season form or developmental stage of M. esculenta. I have only had the opportunity to examine three collections of fresh material that could be considered M. deliciosa. These lacked ascospores indicating immature apothecia. This would tend to support Groves and Hoare's observations. Until more observations are made on Iowa specimens, M. deliciosa should be maintained as a species separate from M. esculenta.

Distribution (Figure 14) Johnson: UI 1905, 1955, 1959; Polk: ISU 1972; Story: RDJ 1974; Webster: RDJ 1974; Winneshiek: RDJ 1975.

Verpa Swartz ex Persoon

Cap-like hymenial area bell-shaped, smooth or lacunose, pendulous from apex of a cylindrical stalk, entire outer surface covered by the yellowish to brown hymenium; stem lighter color than the hymenial area; asci cylindrical, 2- or 8-spored, ascospores elliptical, smooth.

Verpa bohemica (Krombh.) Schroeter (Figure 12)

Bell-shaped or subconic hymenial area yellowish to brownish, white underneath, often with margin slightly reflexed, 2-3 cm in length and reaching a diameter of 1-2 cm; hymenium folded into longitudinal ridges which anastomose rather freely and darken with age; stalk almost cylindric, whitish, hollow or loosely stuffed, not furrowed, reaching a length of 6-8 cm; asci cylindric, tapering into a much contorted stem-like base, entire ascus length 300-325 μm and a diameter of 20-22 μm , usually 2-spored; ascospores elliptical, smooth externally, cytoplasm minutely granular, 60-80 x

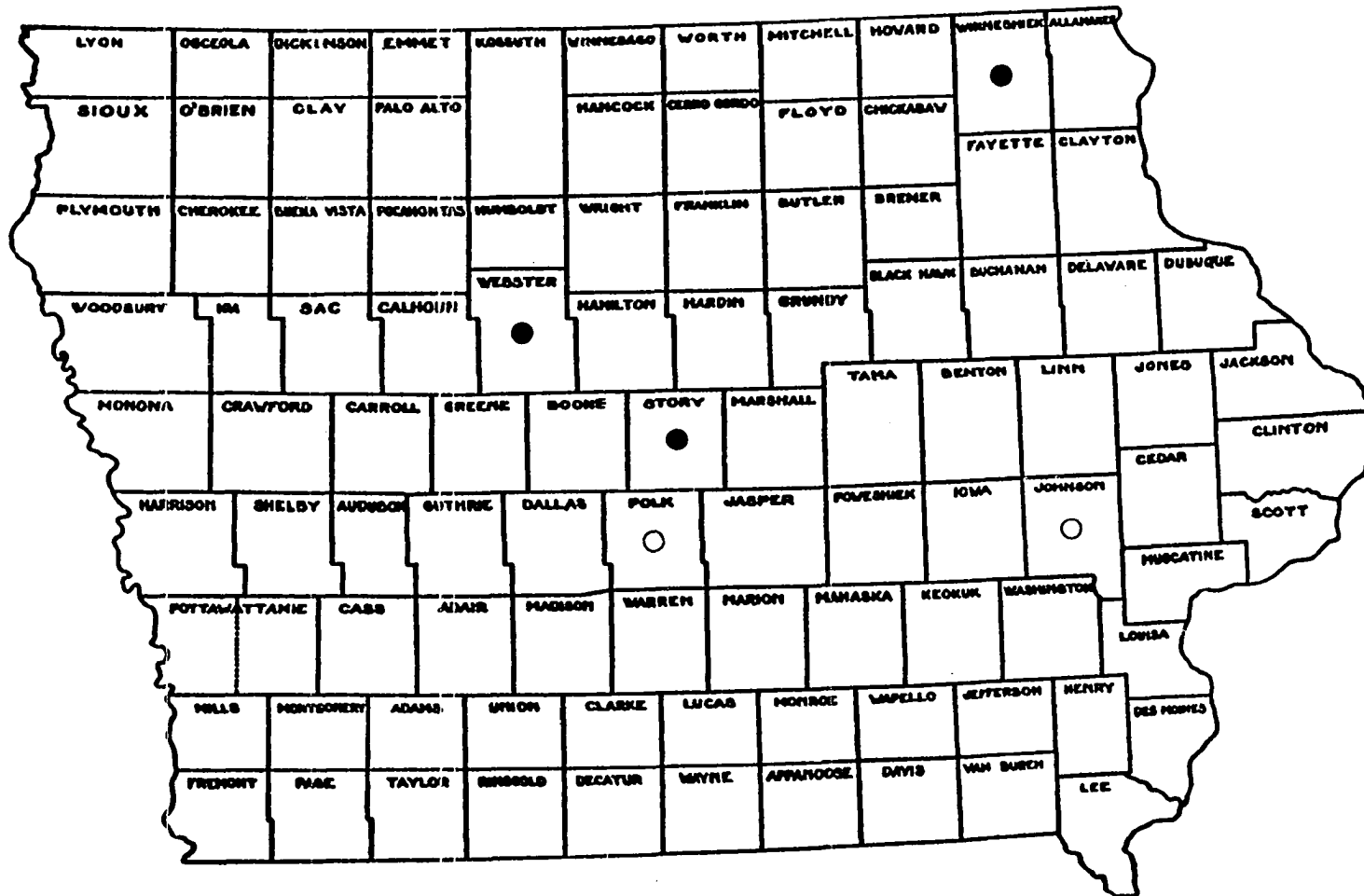


Figure 14. Distribution of Morchella deliciosa Fries in Iowa

15-18 μm , subhyaline or slightly yellowish; paraphyses clavate, having a diameter of 7-8 μm at their apices.

On the ground; spring (late April, early May), appearing before Morchella species. Not common.

Distribution (Figure 15) Dubuque: RDJ 1975; Winneshiek: RDJ 1974, 1975.

Verpa conica Swartz ex Persoon (Figure 18)

Cap-like hymenial area bell-shaped or subconic, whitish beneath, the margin often slightly reflexed; exposing a whitish border, reaching a length of 2 cm and a diameter of 1-2 cm, hymenial area attached only at apex of stem; hymenium olive brown to dark brown, even or slightly lacunose; stalk cylindrical, tapering slightly, hollow or very loosely stuffed, up to 1 cm thick and 5-8 cm long, whitish to cream colored, surface slightly floccose or scaly, the scales giving a transversely striate appearance to the stalk; asci cylindric or subcylindric, tapering to a stem-like base, reaching a length of 300-350 μm and a diameter of 20-23 μm , 8-spored; ascospores uniseriate usually, elliptical, 20-26 x 12-16 μm ; paraphyses slightly clavate, sparingly septate reaching a diameter of 10-12 μm .

In wooded areas on the ground; spring (late April, May). Not common.

Distribution (Figure 16) Boone: RDJ 1975; Johnson: UI 1955; Lee: RDJ 1975; Lucas: RDJ 1975; Pottawattamie: RDJ 1975.

Disciotis venosa (Pers.) Boudier

Apothecia large, often up to 15-20 cm in diameter when fully expanded, solitary or gregarious, discoid or shallow cup-shaped; hymenium dark brown, at first even, becoming ribbed and furrowed, giving a reticulate appearance

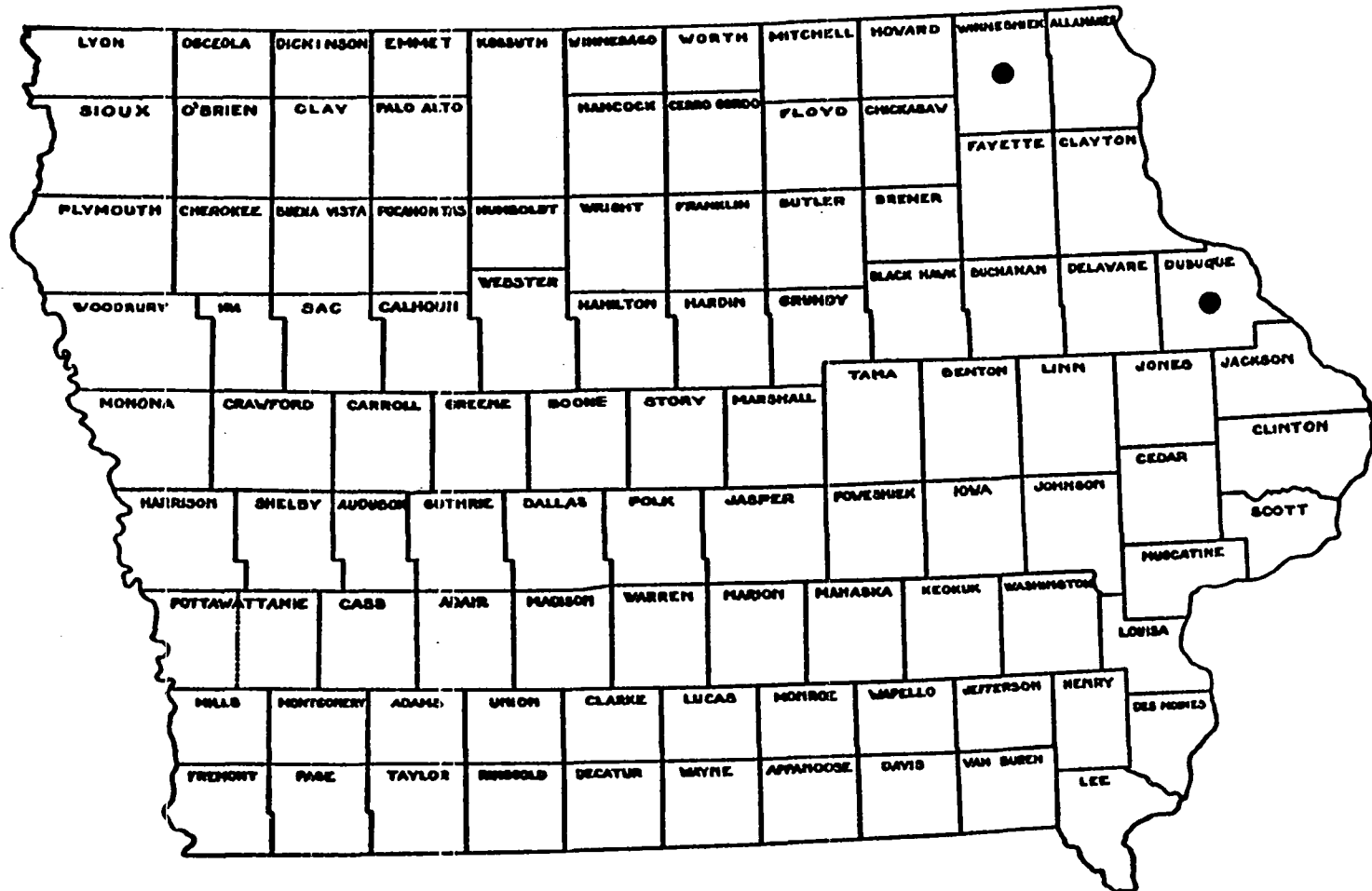


Figure 15. Distribution of *Verpa bohemica* (Krombh.) Schroeter in Iowa

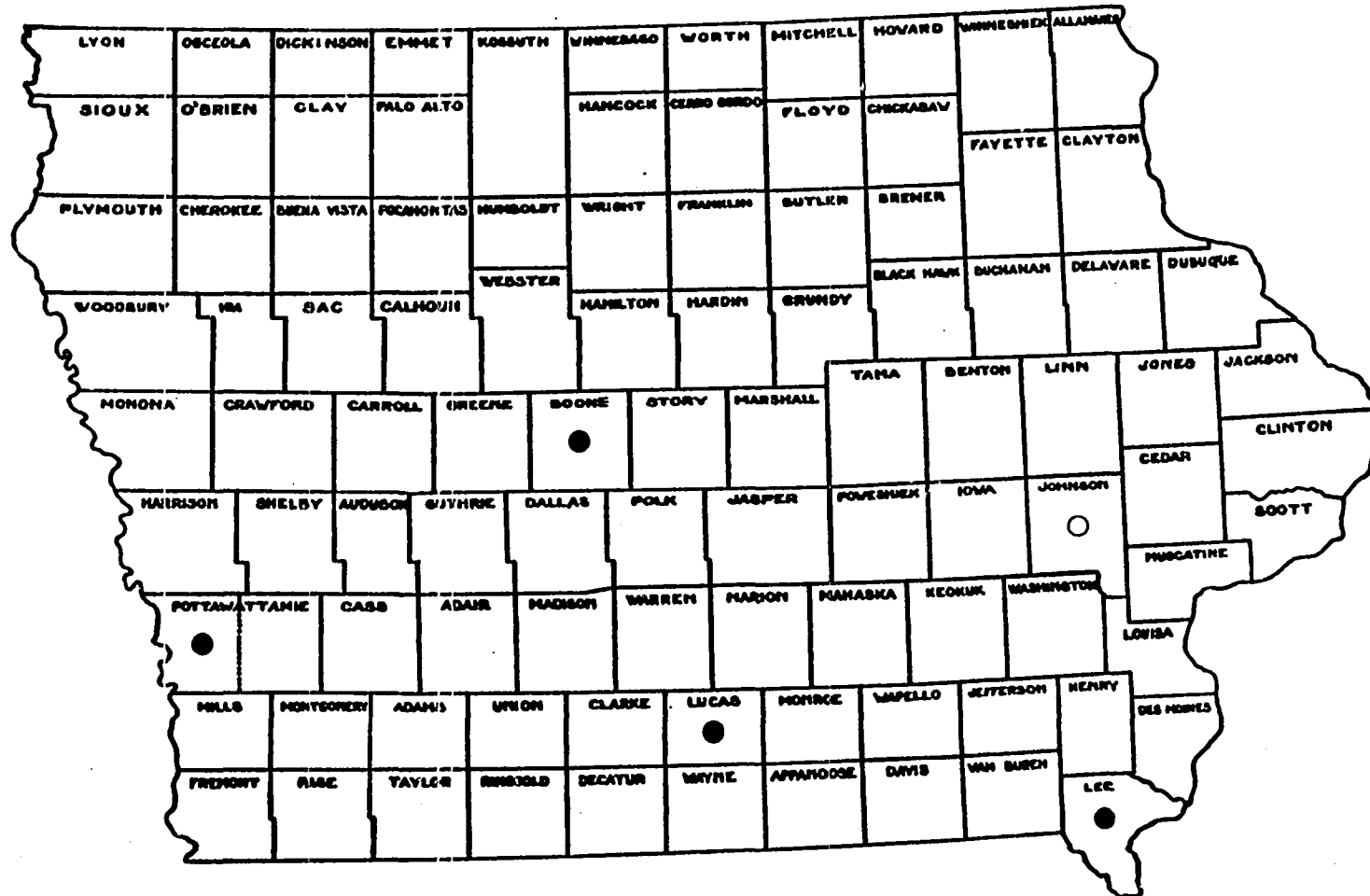


Figure 16. Distribution of Verpa conica Swartz ex Persoon in Iowa

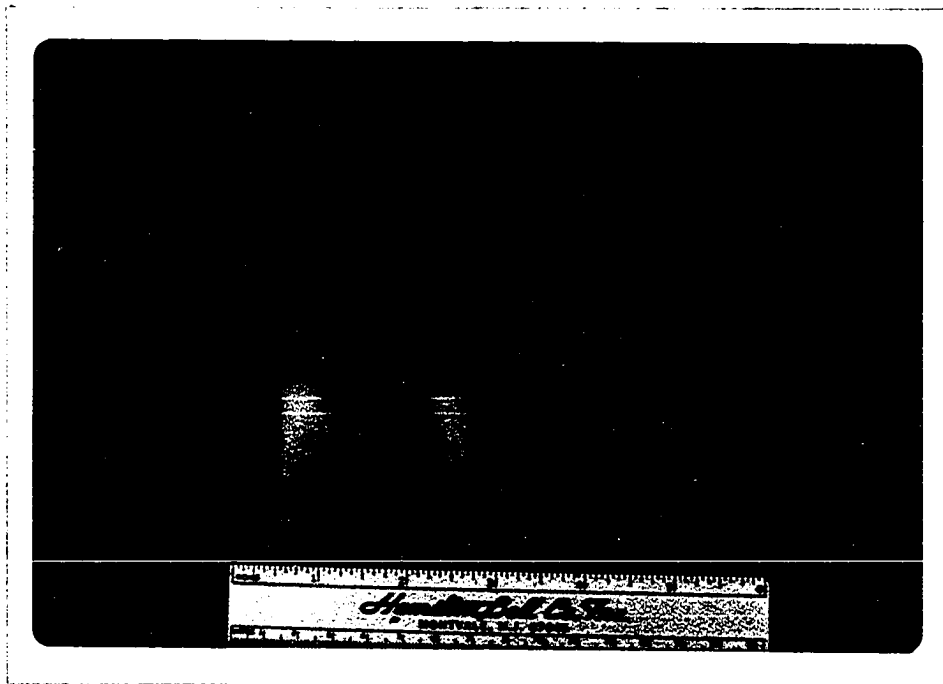


Figure 17. Morchella esculenta (left), Morchella deliciosa (right)

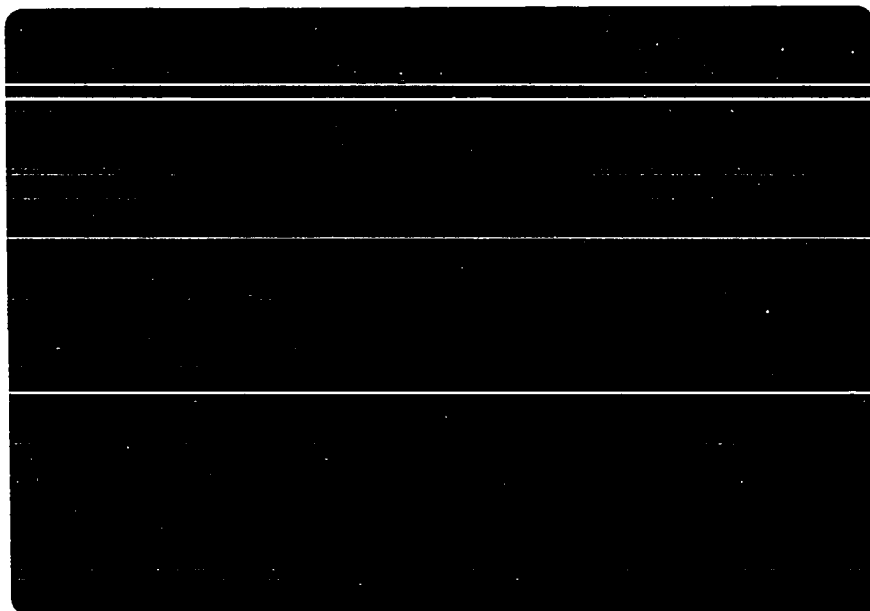


Figure 18. Verpa conica

in large specimens; excipulum whitish, stalk short and stout, sometimes sunk in the soil; asci cylindric or subcylindric, clavate, 280-320 x 20-25 μm , not blue by iodine which distinguishes it from members of the Pezizaceae; ascospores broadly elliptical, (19-)22-25(-30) x 12-17 μm , without conspicuous internal oil drops; paraphyses yellowish-brown, enlarged above, reaching a diameter of 8-12 μm at the apices.

On the ground in deciduous woods; spring (late April, May). Not common.

Distribution (Figure 19) UI 1890 (no location); Webster: RDJ 1974.

Helvellaceae

Apothecia varying from cup-shaped, saddle-shaped to clavate; often lobed, veined, contorted or intricately folded; stalk variable in length and shape; excipulum of textura intricata throughout, or ectal excipulum of textura globosa to textura angularis; asci 8-spored, cylindric, not blue by iodine; ascospores smooth walled, hyaline, contain conspicuous internal oil drops and have no polar granules.

Key to genera and species in Iowa

1. Hymenial area saddle-shaped to somewhat campanulate or irregularly subglobose and convoluted..... 2
2. Hymenial area subglobose and convoluted, irregularly lobed or appearing pitted but never truly pitted as in Morchella; hymenium dark colored..... Gyromitra.. 3
3. Hymenial area appearing reticulate or pitted; stalk usually deeply lacunose..... (G. caroliniana)

3. Hymenial area convoluted; if reticulate, only slightly so;
stalk usually not lacumose..... G. brunnea
2. Hymenial area not as above; whitish, yellowish or dark
colored..... 4
4. Stalk not ribbed and furrowed or only slightly so..... 5
5. Excipulum and stalk whitish to yellowish, hymenium
darker; stalk 3-10 mm in diameter; apothecium
glabrous..... Helvella elastica
5. Excipulum and stalk grayish, hymenium black or nearly so;
stalk 2-4 mm in diameter; apothecium usually pubescent..
..... (Helvella atra)
4. Stalk definitely ribbed and furrowed..... 6
6. Hymenial area saddle-shaped; ribs of stalk sharp edged;
hymenium whitish to grayish..... 7
7. Hymenium and stalk whitish; excipulum pubescent.....
..... Helvella crispa
7. Hymenium and stalk gray to grayish-brown; excipulum
glabrous..... (Helvella lacunosa)
6. Hymenial area convex or campanulate, not saddle-shaped;
ribs of stalk not sharp edged; hymenium dark brown.....
..... (Helvella queletiana)
1. Hymenial area cup-shaped or clavate to columnar..... 8
8. Hymenial area cup-shaped, mature spores smooth..... 9
9. Stalk 1-4 cm long, slender; cup usually shallow and grayish
..... Helvella villosa

9. Stalk short, 1-2 cm long, stout, usually ribbed and furrowed, ribs extending up the sides of the cup; deep cupped; cup brownish..... Helvella acetabulum
8. Hymenial area clavate or columnar; mature spores rough.....
..... (Underwoodia columnaris)

Gyromitra Fries

Apothecia ovoid, large, becoming irregularly lobed and convoluted but not pitted as in Morchella spp., the hymenial area adhering closely to the stalk and sometimes united with it at intervals; stalk short, stout, hollow or chambered, often furrowed or ridged externally; asci cylindric or subcylindric; ascospores elliptical, smooth or rough; paraphyses slightly clavate, broad, septate.

Gyromitra brunnea Underwood (Figure 21)

Hymenial area much contorted, irregularly lobed and plicate, sometimes having indistinct anastomosing ridges, adhering to the stalk at various points, reaching a diameter of 5-12 cm, whitish underneath, hymenium dark brown; stalk reaching a length of 8-13 cm and a diameter of 2-5 cm, even or occasionally slightly lacunose, hollow or loosely stuffed, white; asci cylindric or subcylindric; ascospores elliptical, 28-30 x 14 μ m, hyaline, usually containing two rather large oil drops, becoming sculptured with small warts or faint reticulations; paraphyses slender, enlarged above.

In wooded areas on the ground; spring (May). Not common.

Distribution (Figure 20) Boone: RDJ 1975; Cedar: UI 1955; Decatur: GC 1972; Guthrie: RDJ (1973); Johnson: UI 1931, 1933, 1936, 1940; Polk: RDJ 1975; Pottawattamie: RDJ 1975; Story: RDJ 1975; Van Buren: RDJ 1975;

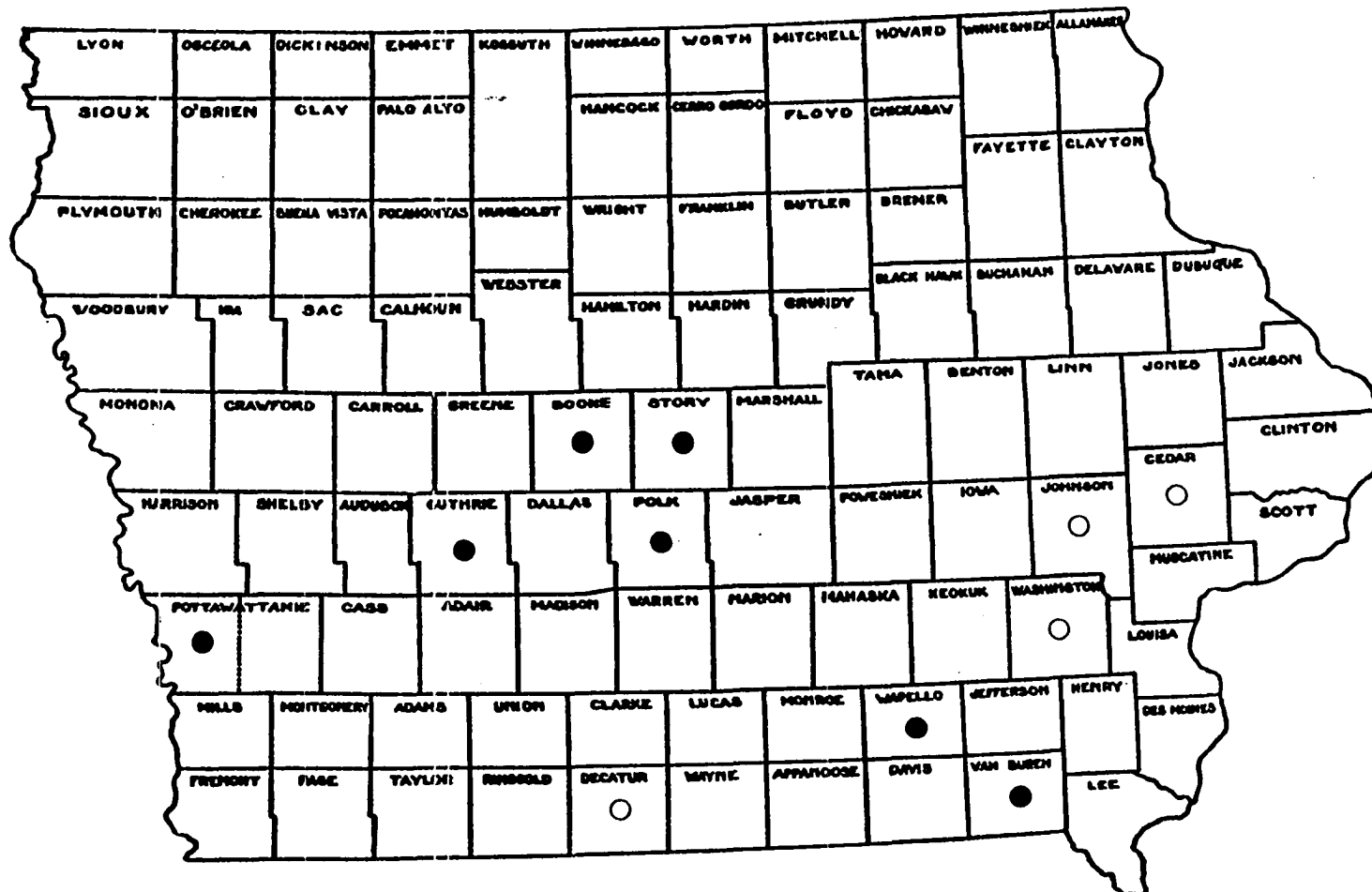


Figure 20. Distribution of *Gyromitra brunnea* Underwood in Iowa

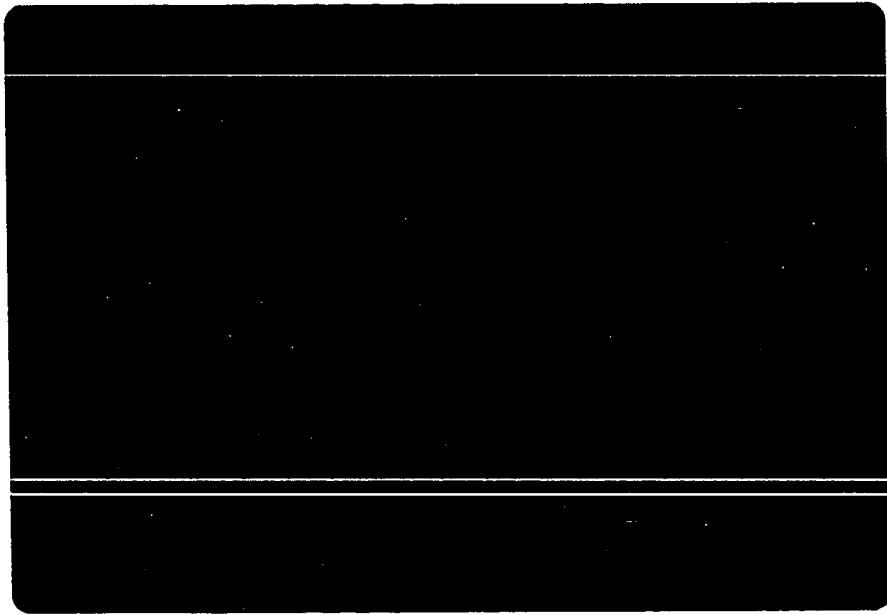


Figure 21. Gyromitra brunnea

Wapello: RDJ (1973); Washington: UI 1931.

Helvella Linnaeus ex St. Amans

Apothecia stalked, sterile surfaces glabrous or pubescent, the hymenial area cup-shaped or saddle-shaped with two or three lobes strongly reflexed and appressed to the stalk; hymenium usually whitish to grayish or darker; stalk cylindrical, even or ribbed and furrowed; asci 8-spored, ascospores elliptical with one large central oil drop; paraphyses slender, enlarged above.

Helvella elastica Bull. ex St. Amans (Figure 24)

Hymenial area saddle-shaped, irregularly 2-3 lobed, the margin reflexed and usually free from the stalk; reaching a diameter of 2-3 cm, grayish or yellowish when fresh, drying to dark brown or nearly black; stalk slender, cylindrical, 3-10 mm in diameter, 5-10 cm in length, hollow, whitish to yellowish, smooth, never fluted; asci cylindric or subcylindric, 200-250-330 x 20 μ m; ascospores uniseriate, elliptical, containing one large oil drop, 18-20 x 10-13 μ m; paraphyses cylindric to clavate, enlarged above reaching a diameter of 10 μ m.

On the ground in wooded areas; summer, fall (June-September). Not as common as H. crispa.

Distribution (Figure 22)

Boone: RDJ 1973; Cerro Gordo: UI 1920; Dickinson: ISU 1932, RDJ 1975; Emmet: ISU (1968), 1970, (1972), UI 1928; Johnson: UI 1905, 1913, 1914, 1938, UI 1924, 1942 (as H. atra); Story: RDJ 1973; Webster: RDJ 1973; Winneshiek: LC 1896 (as H. gracilis Peck).

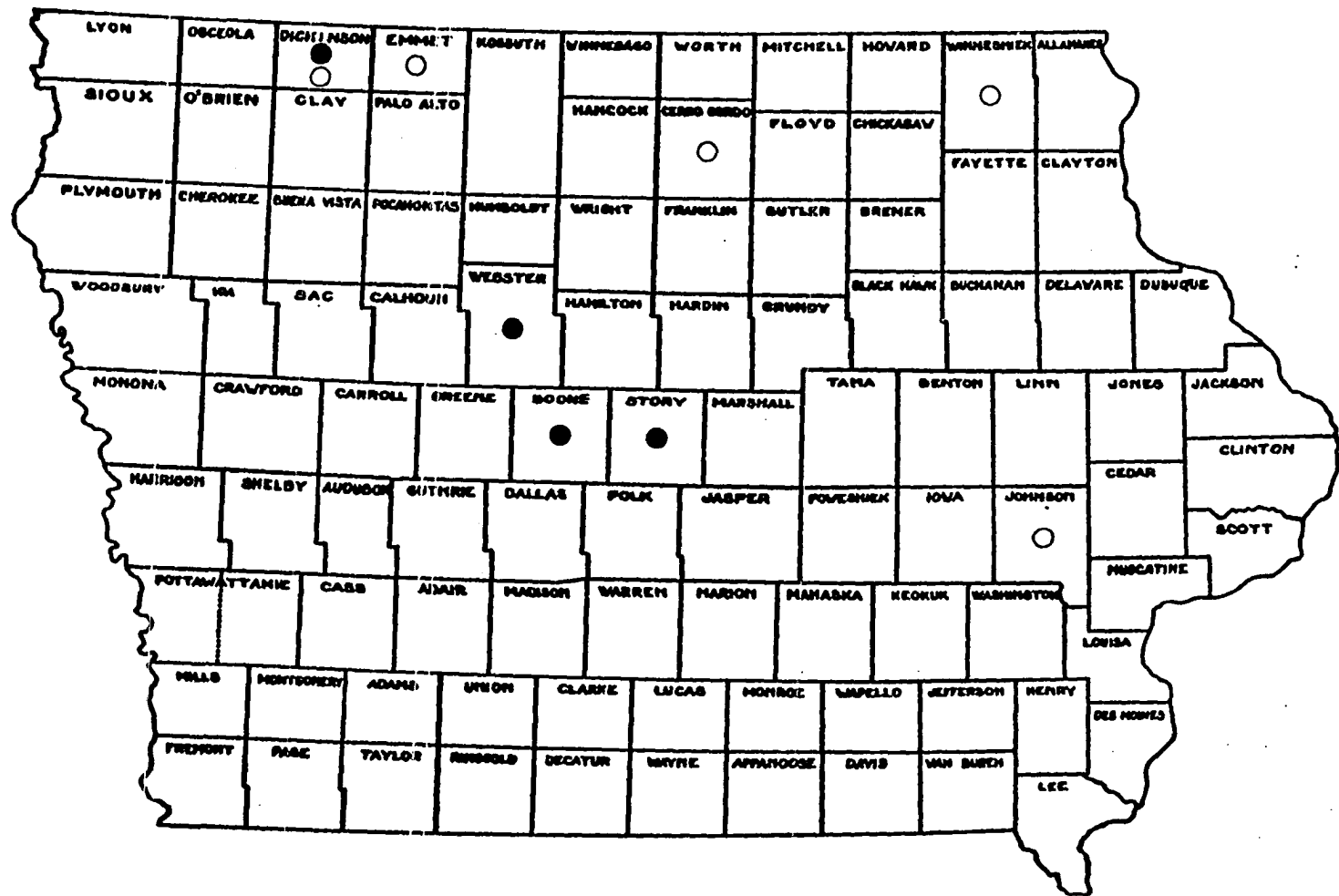


Figure 22. Distribution of *Helvella elastica* Bull. ex St. Amans

Helvella crispa Fries (Figure 25)

Apothecia up to 10 cm high, hymenial area usually saddle-shaped, sometimes mitrate, reflexed and usually irregularly lobed, reaching a diameter of 4-5 cm; hymenium white at first, becoming cream or yellowish with age and/or drying; stalk cylindric, stout, hollow, reaching a length of 6-7 cm and a diameter of 2-3 cm, deeply fluted with longitudinal furrows, color similar to hymenial area; asci cylindric or subcylindric, reaching a length of 300 μm and a diameter of 15-18 μm ; ascospores uniseriate, elliptical, 18-20 x 10-13 μm , containing one large oil drop; paraphyses cylindrical, enlarged above, reaching a diameter of 6-8 μm at the tips.

On soil in moist woods; summer, fall (July-October). Fairly common.

Distribution (Figure 23)

Boone: RDJ 1975; Decatur: RDJ 1973; Emmet: ISU (1964), (1968), 1970, (1972), UI 1932; Fremont: RDJ 1973, 1974; Hancock: ISU (1962); Harrison: RDJ 1973; Johnson: UI 1924; Pottawattamie: RDJ 1973; Story: RDJ 1975; Winneshiek: 1885, UI 1903.

Helvella villosa (Hedw. ex Kuntze) Dissing and Nannf.

Apothecia up to 4 cm high, often shorter; hymenial area cup-shaped, somewhat discoid with age, 1-2.5 cm in diameter and reaching a depth of 0.5-1 cm, hymenium grayish, excipulum concolorous and pubescent, pubescence due to conical bunches of hyaline hairs which cling together in fascicles; stalk cylindrical 1-2 cm in length, 2-3 mm in diameter, concolorous with the cup or lighter colored, especially toward the base; asci cylindric or slightly clavate above, reaching a length of 275 μm and a diameter of 12-17 μm , tapering below into a stem-like base; ascospores uniseriate, elliptical, smooth, usually containing only one large oil drop, 17-21 x 9-12 μm ; para-

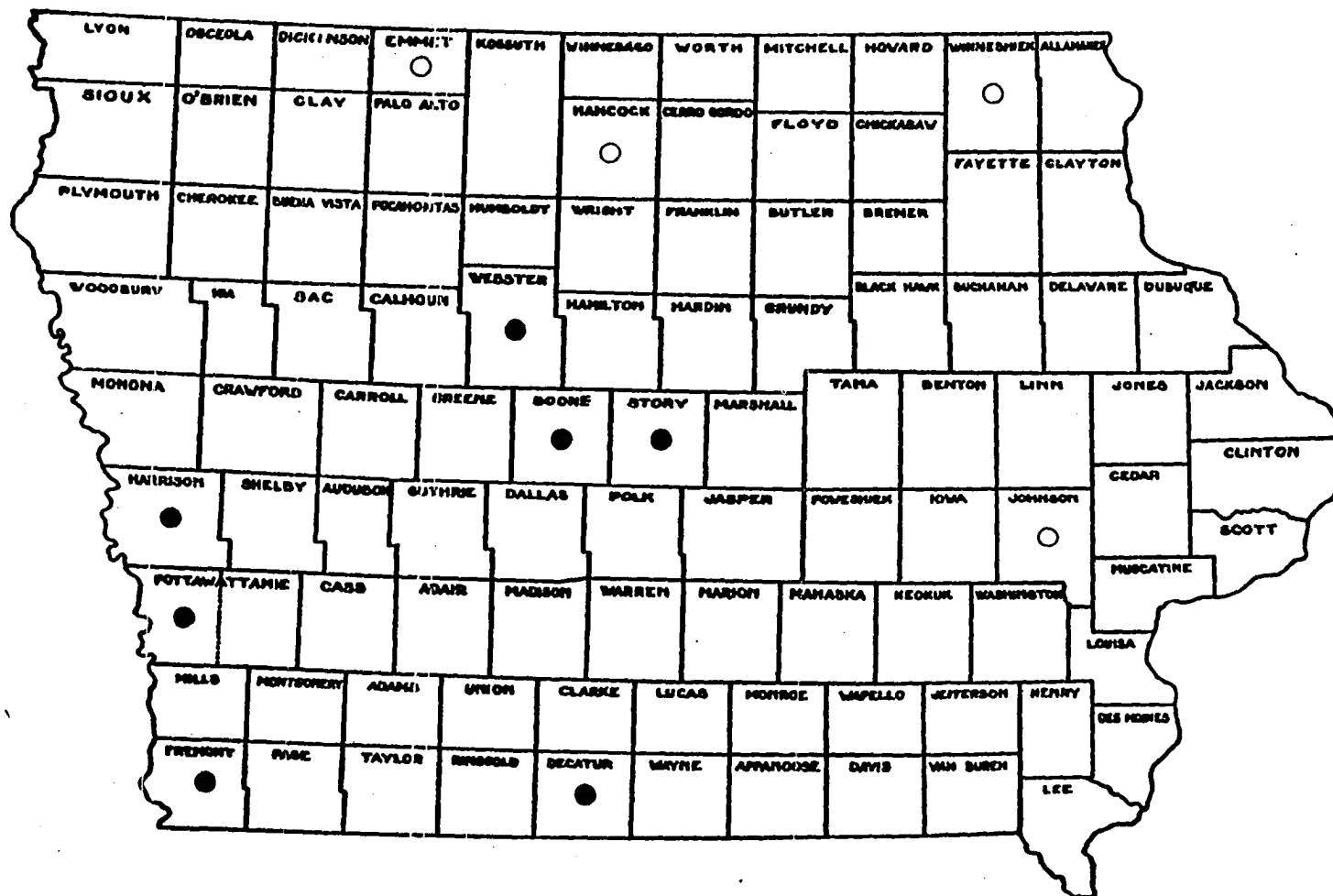


Figure 23. Distribution of *Helvella crispa* Fries in Iowa

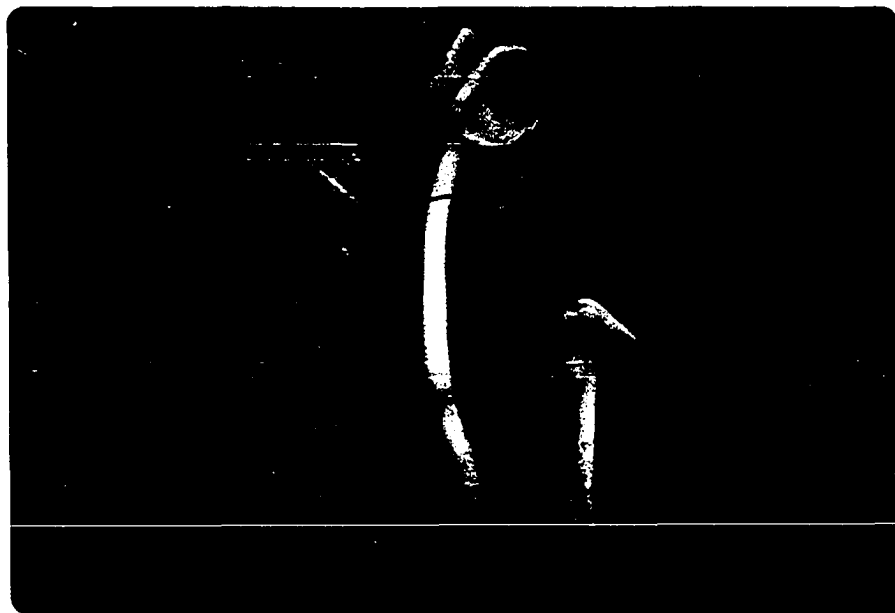


Figure 24. Helvella elastica

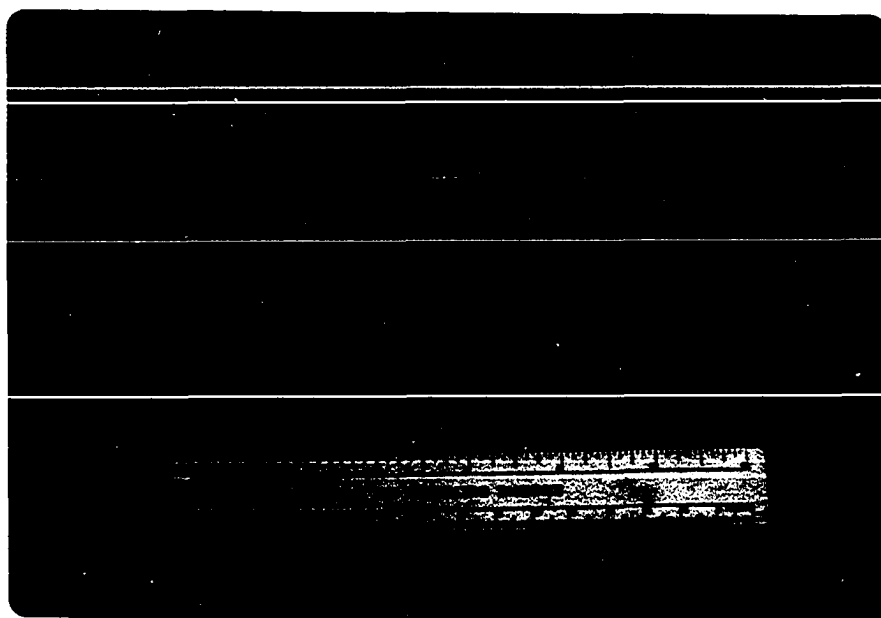


Figure 25. Helvella crispa

physes clavate.

On ground in wooded areas; summer, fall (July-October). Fairly common.

The Iowa specimens are quite variable in size and color of the apothecia. On the basis of spore size, specimens could be identified as Paxina subclavipes (Phill. and Ellis) Seaver (Seaver, 1942) or Cyathipodia villosa (Hedw. ex Kuntze) Boudier (Dennis, 1968). On the basis of apothecia, size, and color, one might place the same specimens in Paxina hispida (Schaeff.) Seaver (Seaver, 1942). It is felt that the Iowa specimens attributed to the above three species are the same species and can best be characterized by the above description which is adapted from Dissing (1966). Dissing considers Paxina and Cyathipodia synonyms of Helvella.

Distribution (Figure 26) Allamakee: RDJ 1973, 1974; Boone: ISU 1969, RDJ 1973, 1974; Decatur: RDJ 1973; Dickinson: ISU (1972); Emmet: ISU (1964), 1970, (1972), RDJ 1974; Fremont: RDJ 1974; Johnson: UI 1904, 1926 (as H. macropus [Pers.] Kuntze), UI 1923, 1924, 1929 (as Macropodia macropus [Pers.] Fuck.), UI 1935 (as Paxina subclavipes), UI 1938, 1943 (as Paxina hispida); Kossuth: RDJ 1973; Webster: ISU (1962), RDJ 1973; Winne-shiek: ISU (1882) (as Paxina subclavipes).

Helvella acetabulum (Linn. ex St. Amans) Quel. (Figure 28)

Apothecia usually deep cup-shaped, cups 2-3 cm in depth and 3-6 cm in diameter; hymenium dark brown, excipulum of cup lighter and minutely downy; stalk short and stout, whitish to brown colored, reaching a length of 1-1.5 cm and a diameter of 1 cm, conspicuously ribbed and furrowed, the ribs often passing upwards into prominent forked veins of the underside of the cup;

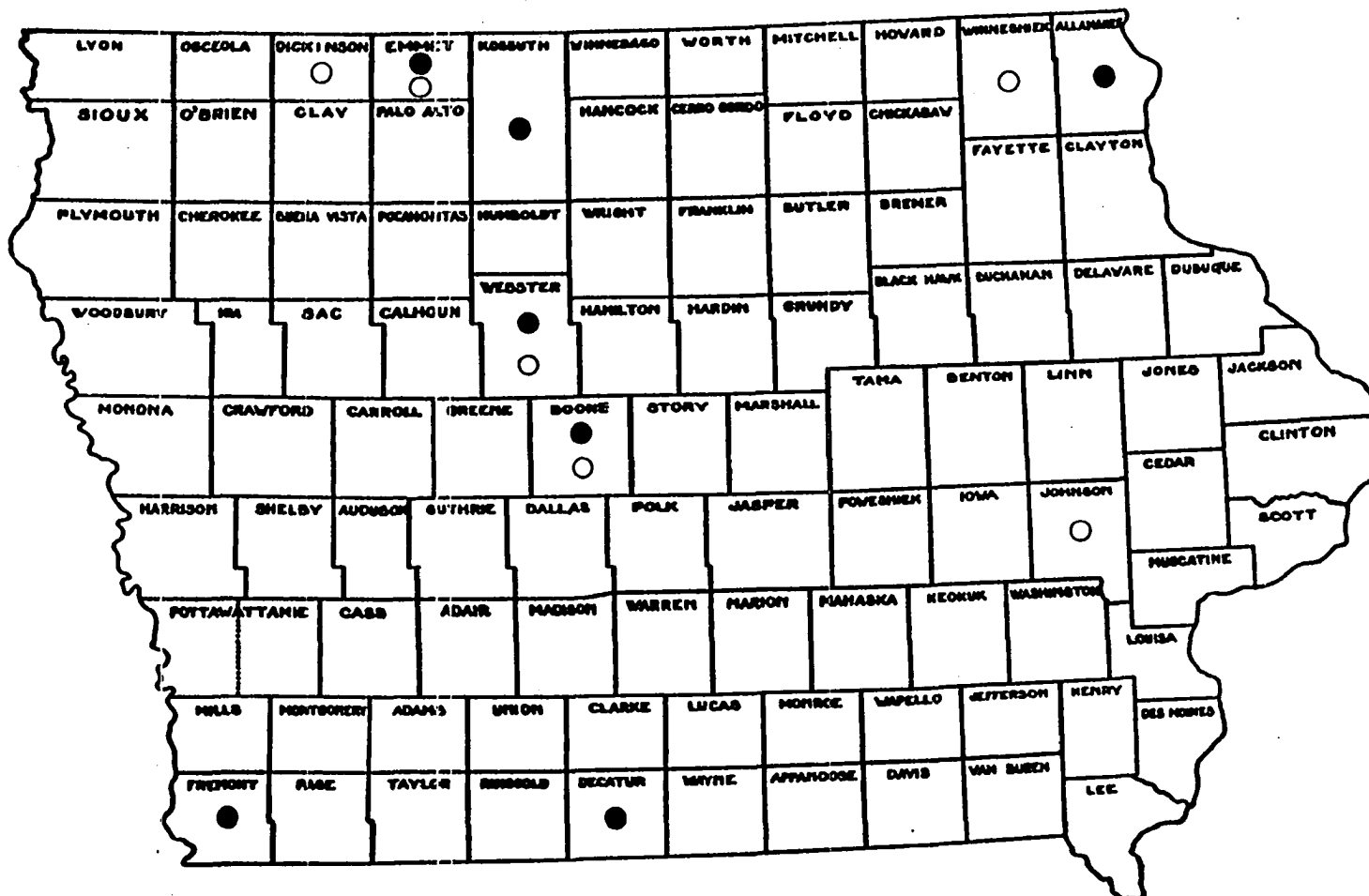


Figure 26. Distribution of *Helvella villosa* (Hedw. ex Kuntze) Dissing and Nannf. in Iowa

asci cylindric, 400 x 20 μ m; ascospores uniseriate, broadly elliptical, 18-22 x 12-14 μ m, hyaline, each containing one oil drop; paraphyses somewhat clavate, 5-6 μ m in diameter at the apices.

On the ground in wooded areas; late spring, early summer (May-July).

Not common.

Distribution (Figure 27) Boone: mid 1960's; RDJ (1973); Dickinson: UI 1932 (as Acetabula vulgaris Fuck.); Emmet: ISU (1972); Iowa: UI 1938; Johnson: UI 1938; Story: RDJ (1973); Winneshiek: ISU 1885.

Several other species of the Helvellaceae have been collected in Iowa and are represented by herbarium specimens. I have not seen or collected any fresh specimens of these species. This does not imply that they are no longer present in Iowa but only that they probably are not common and do not occur regularly or in great numbers. The distribution is given for each species.

The species are:

Gyromitra caroliniana (Bosc.) Fries (Figure 29)

Boone: ISU 1969; Muscatine: UI 1956 (as G. brunnea); Washington: UI 1959 (as G. brunnea)

Helvella atra Holmskj. ex Fries

Dickinson: UI 1951

Helvella lacunosa Afz. ex Fries

Johnson: UI 1923, 1926 (as H. mitra)

Helvella queletiana Sacc. and Trav.

Johnson: UI 1924

Underwoodia columnaris Peck (Figure 30)

Boone: ISU 1971; Emmet: UI 1932

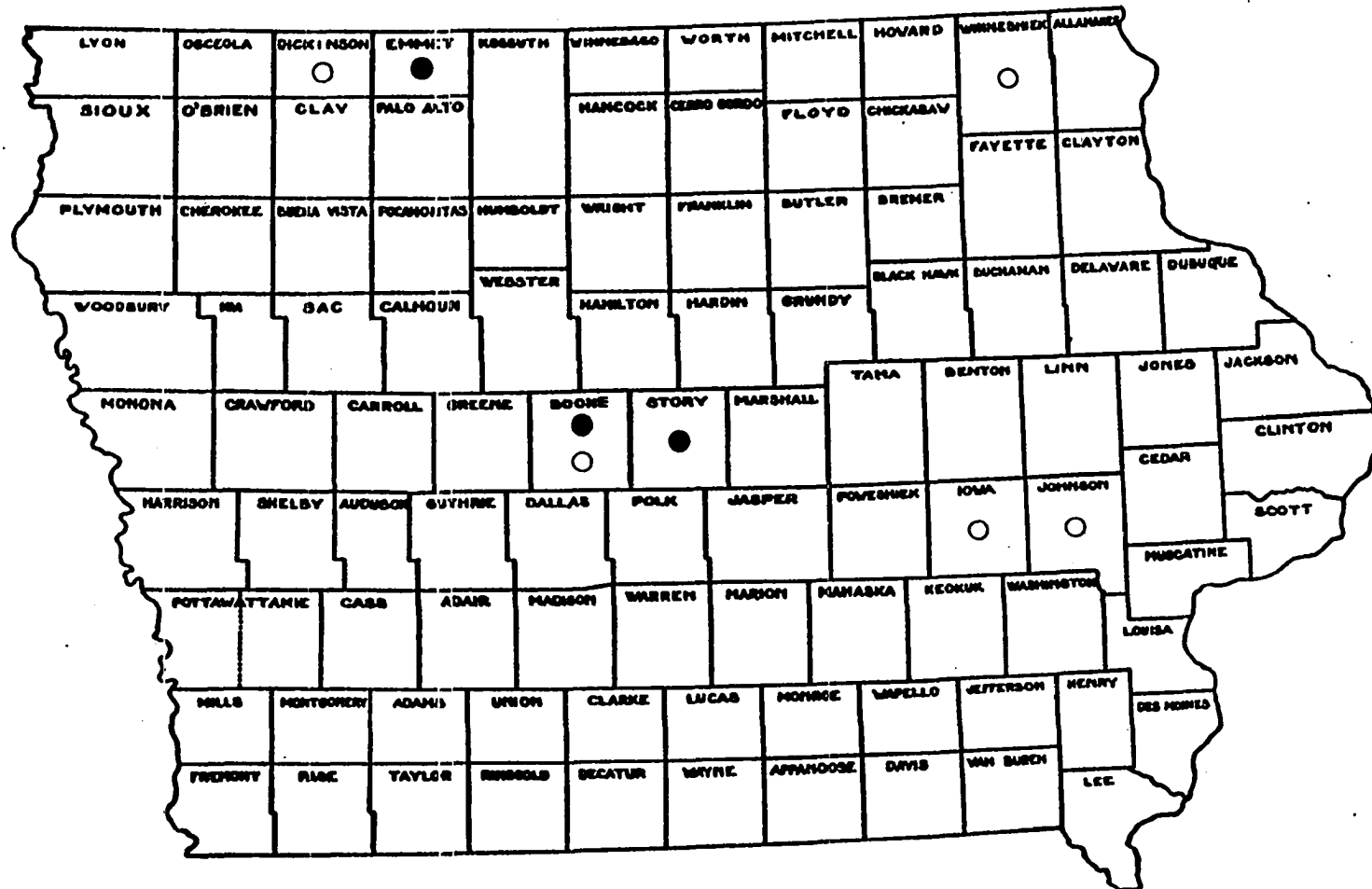


Figure 27. Distribution of *Helvella acetabulum* (Linn. ex St. Amans) Quel. in Iowa



Figure 28. Helvella acetabulum

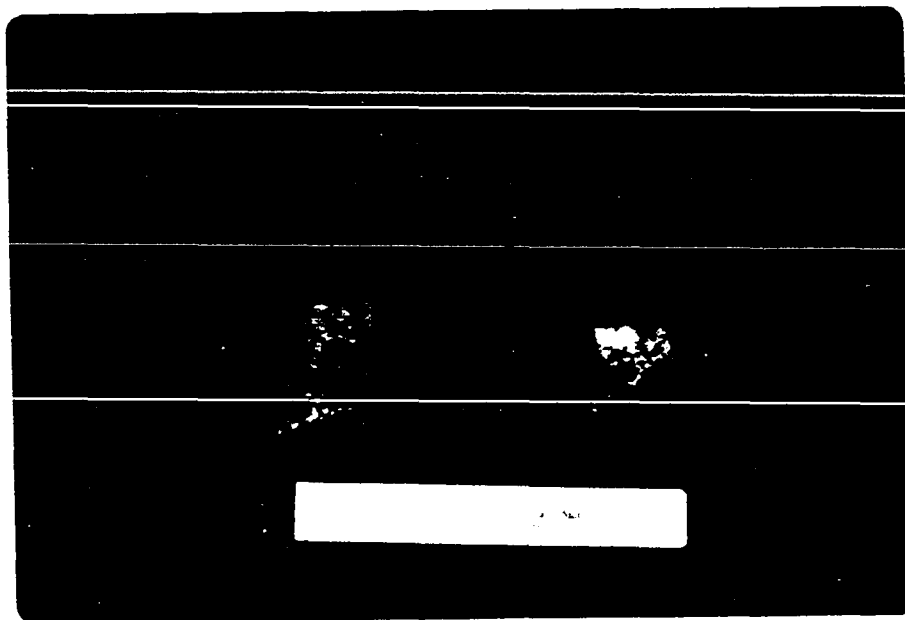


Figure 29. Gyromitra caroliniana

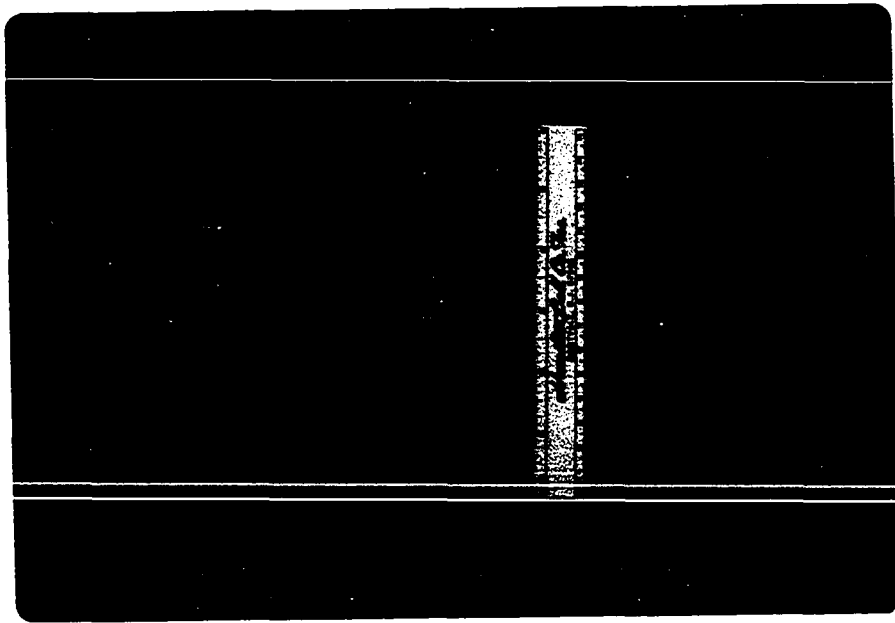


Figure 30. Underwoodia columnaris

Geoglossaceae

Apothecia mostly club-shaped or clavate with the hymenium forming a uniform layer over part, occasionally all, of the apothecium or with an irregular head or cap-like structure with the hymenium covering the upper surface only; ectal excipulum lacking (Korf, 1973); asci inoperculate, 8-spored usually; ascospore shape and color variable.

Key to genera and species in Iowa

1. Apothecia with a subglobose to irregular head or cap-like structure bearing the hymenium; gelatinous, yellowish or greenish; apothecia usually densely clustered; ascospores oblong to fusiform, less than 30 μm in length..... Leotia.. 2
2. Apothecia yellowish, often with light green tint.... L. lubrica
2. Apothecia green, at least the hymenial area green..... 3
 3. Apothecia entirely green..... (L. atrovirens)
 3. Hymenial area green, stalk usually whitish or less often yellowish..... (L. viscosa)
1. Apothecia spathulate or clavate, not gelatinous, yellowish or brownish-black; ascospores filiform, greater than 30 μm in length..... 4
4. Apothecia spathulate or fan-shaped; yellowish; hymenial area flattened..... Spathularia flavida
4. Apothecia clavate, brownish-black; hymenial area lanceolate, hymenium having spines or setae..... (Trichoglossum walteri)

Leotia lubrica Persoon (Figure 33)

Apothecia clustered, reaching a height of 3-6 cm or more, hymenium borne on a cap-like structure which is convex above, 1-1.5 cm in diameter, surface often irregularly furrowed, with a recurved margin, yellowish-green to olivaceous, somewhat viscid and gelatinous, stalk cylindrical or tapering, less than 1 cm in diameter, yellowish, flattened, sometimes dotted with greenish granules; asci clavate, 130-160 x 10-12 μ m, 8-spored, biseriate above, uniseriate below; ascospores hyaline, smooth, slightly fusiform with rounded ends, straight or curved, (18-)20-23(-28) x 5-6 μ m, becoming 5-7 septate; paraphyses filiform, branched, with clavate tips.

On damp, rich humus or sandy soil; summer, fall (July-October). Fairly common.

Distribution (Figure 31) Black Hawk: UI 1915; Boone: ISU 1969?; Dickinson: ISU 1972; Decatur: RDJ 1973; Emmet: ISU (1962), (1968), (1970), 1972; Hancock: ISU (1962); Hardin: RDJ 1975; Johnson: UI 1904, 1923, 1924, 1936; Story: RDJ 1975; Webster: RDJ 1973.

The only specimens of L. atrovirens Pers. (as L. chlorocephala Schw.) and L. viscosa Fries (as L. stipitata [Bosc.] Schrot.) that I have seen are in the University of Iowa herbarium. They were collected in Johnson County. The main character for distinguishing the three Leotia species is in the color of the apothecium. They cannot be readily distinguished on the basis of other characters (e.g., ascospore size, shape, septation; ascus size; size and shape of the apothecium, etc.). Leotia atrovirens and L. viscosa are currently considered separate species (Korf, 1973).

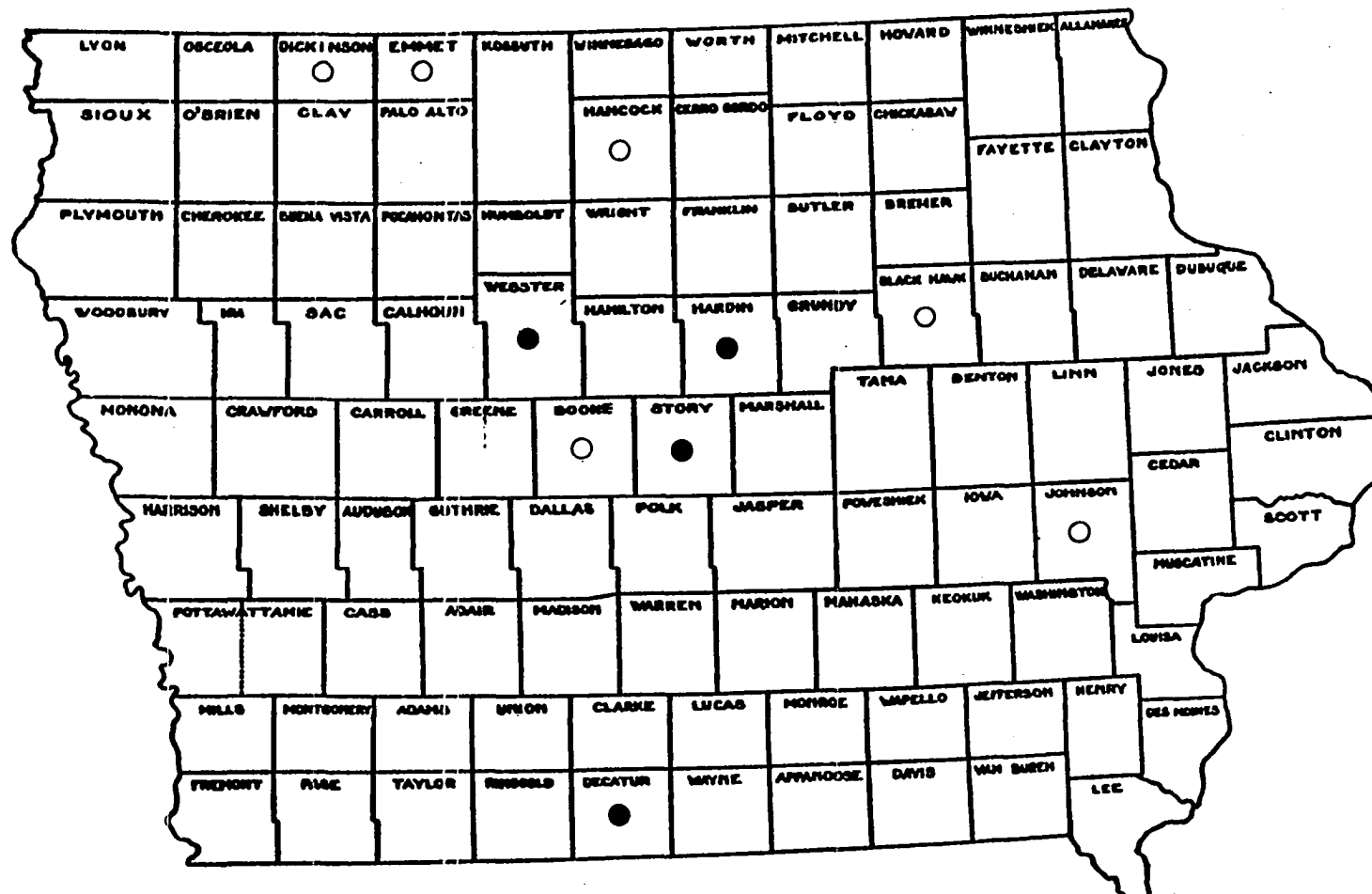


Figure 31. Distribution of Leotia lubrica Pers. in Iowa

Spathularia flavida Persoon ex Fries (Figure 34)

Apothecia usually solitary, fleshy, up to 10 cm high; hymenial area flattened, fan-shaped, obtuse or rounded, even or undulating, decurrent on opposite sides of the stalk, occupying about one-third to one-half of the total length of the apothecium, yellowish or brownish when mature, pallid when young; stalk hollow, slender, tapering slightly upwards, paler than the hymenium; asci clavate, reaching a length of 100-125 μm and a diameter of 12-14 μm , 8-spored; ascospores lying parallel in the ascus, clavate-filiform, becoming multiseptate, hyaline, 40-50 x 2-3 μm ; paraphyses filiform, branched, hyaline, curled or coiled at the apices.

On soil or humus, usually in coniferous woods; summer (August). Not common.

Distribution (Figure 32) Dubuque: ISU 1971, UI 1953, RDJ 1973; Winneshiek: ISU 1883 (in 'North American Fungi', #1268).

As far as is known only one species of Trichoglossum, T. walteri (Berk.) Durand, has been collected in Iowa. The only specimen known was collected on the Sphagnum mat in Pilot Knob State Park, Hancock County, and is in the Iowa State University herbarium.

Sclerotiniaceae

Apothecia arise from sclerotia or stromata associated with host plants; apothecia soft-fleshed, often long stalked and frequently yellowish-brown to brown in color; inner layers of the excipulum and stalk of a textura intricata, outer layers of hyphae almost perpendicular to the surface and composed of broader and shorter cells forming a compact tissue (Dennis, 1956); asci inoperculate, usually large and thin-walled; ascospores ellip-

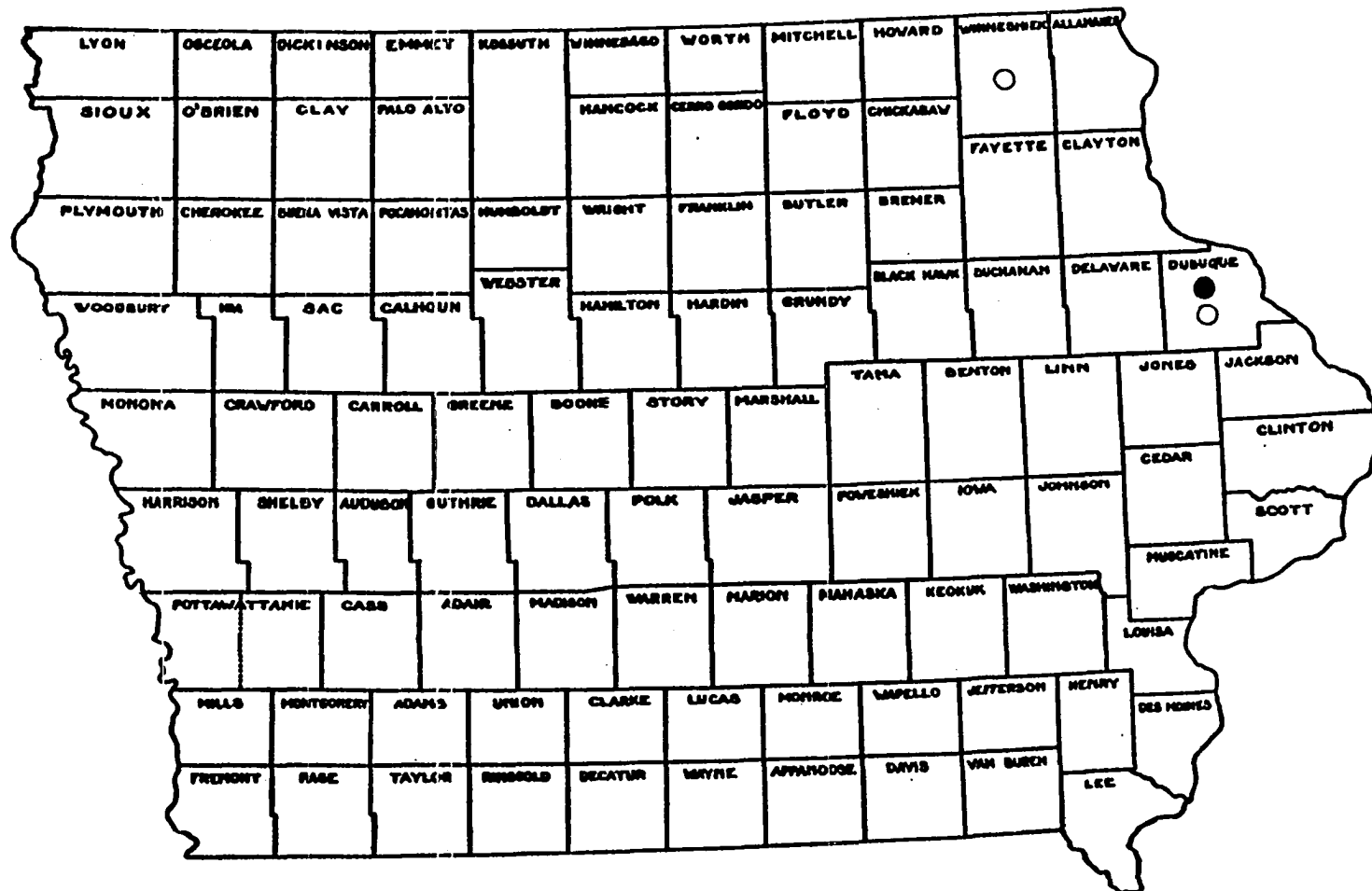


Figure 32. Distribution of *Spathularia flavida* Pers. ex Fries in Iowa

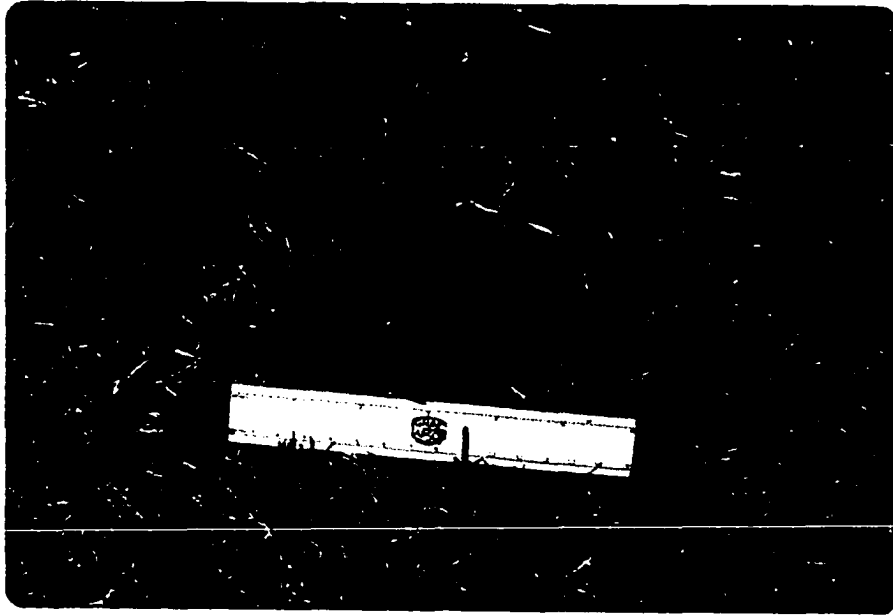


Figure 33. Leotia lubrica

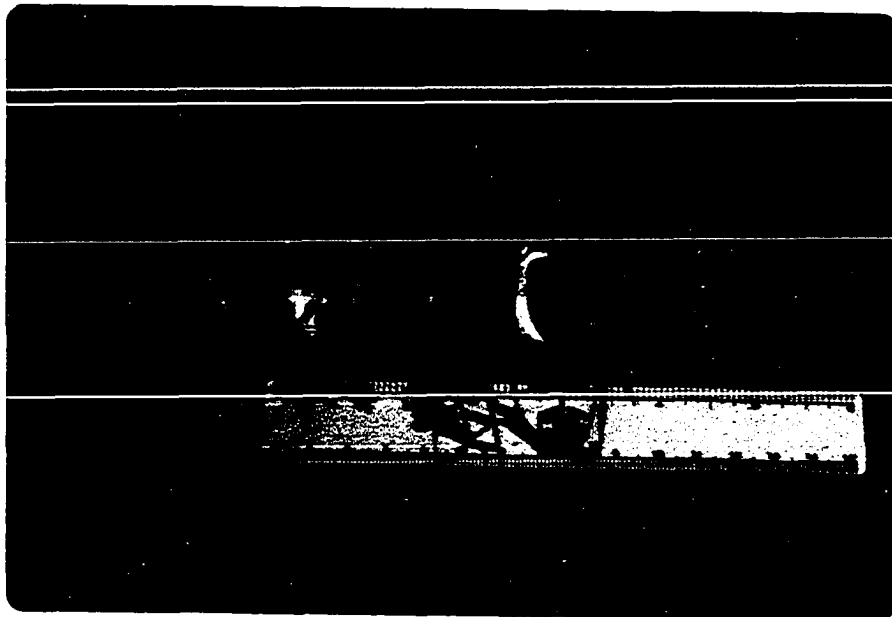


Figure 34. Spathularia flavida

tical, usually hyaline and one celled; most members of this family parasitic; a conidial state commonly present in some genera and/or species.

Key to genera and species in Iowa

1. Apothecia arising directly from well developed black sclerotia
(5-6 mm in diameter) which may or may not be directly associated
with plant tissue..... Sclerotinia tuberosa
1. Apothecia not arising directly from sclerotia..... 2
 2. Apothecia arising from sclerotium-like growth within seeds or
fruits of host..... 3
 3. On old acorn cotyledons..... Ciboria pseudotuberosa
 3. On overwintered mummified stone fruits.....
..... Monilinia fructicola
 2. Apothecia arising from another part of the host..... 4
 4. Small black sclerotia, 1-2 mm in diameter, present in host
tissue but apothecia not arising directly from them; apothecia
on decaying rhizomes of Smilacina racemosa; ascospores
nonseptate..... Stromatinia smilacinae
 4. Sclerotia absent; apothecia usually associated with stromatized
portion of host tissue; ascospores often one to several
septate..... Rutstroemia.. 5
 5. Apothecia occurring on wood or woody tissue..... 6
 6. Apothecia pale brown, ascospores 25-35 μ m long.....
..... R. macrospora
 6. Apothecia darker brown, ascospores 14-22 μ m long.....
..... R. firma

5. Apothecia on other substrate; on decaying leaves of broad-leaved trees; apothecia yellowish when fresh, drying darker; spores 10-14 μm long..... R. longipes

Sclerotinia Fuckel

Apothecia arising from a well developed tuberoid, elongated or irregular sclerotium having a black exterior and white interior; sclerotia formed in or on plant host tissue but often appearing unassociated with any host due to decay of the host tissue; apothecia cup-shaped, sometimes becoming discoid with age; asci 8-spored; ascospores ellipsoid to fusoid, hyaline and nonseptate.

Sclerotinia tuberosa ([Hedwig] Fries) Fuckel (Figure 37)

Apothecia cup-shaped, 1-2 cm in diameter, arising from sclerotia buried in the ground; sclerotia 5-7 mm in diameter with black exterior and white interior, each sclerotium usually producing only one apothecium; plant host unknown but may be Anemone sp. according to Dennis (1968); apothecia light brown, hymenium darker than excipulum; stalk slender, about 2 mm in diameter, length variable, often up to 10 cm long; asci cylindric-clavate, 150-170 x 8-10 μm , 8-spored, the pore blued by iodine; ascospores uniseriate, ellipsoid, hyaline, with small oil drop in each end, 12-17 x 6-9 μm ; paraphyses filiform, slightly enlarged above, 3-4 μm in diameter.

Wooded areas on sclerotia buried in ground; spring (April-May). Not common.

Distribution (Figure 35)

Boone: ISU (1962); Iowa: RDJ 1974; Johnson: UI 1927, 1935; Story: ISU (no date), RDJ 1974; Winneshiek: ISU 1882, RDJ 1975.

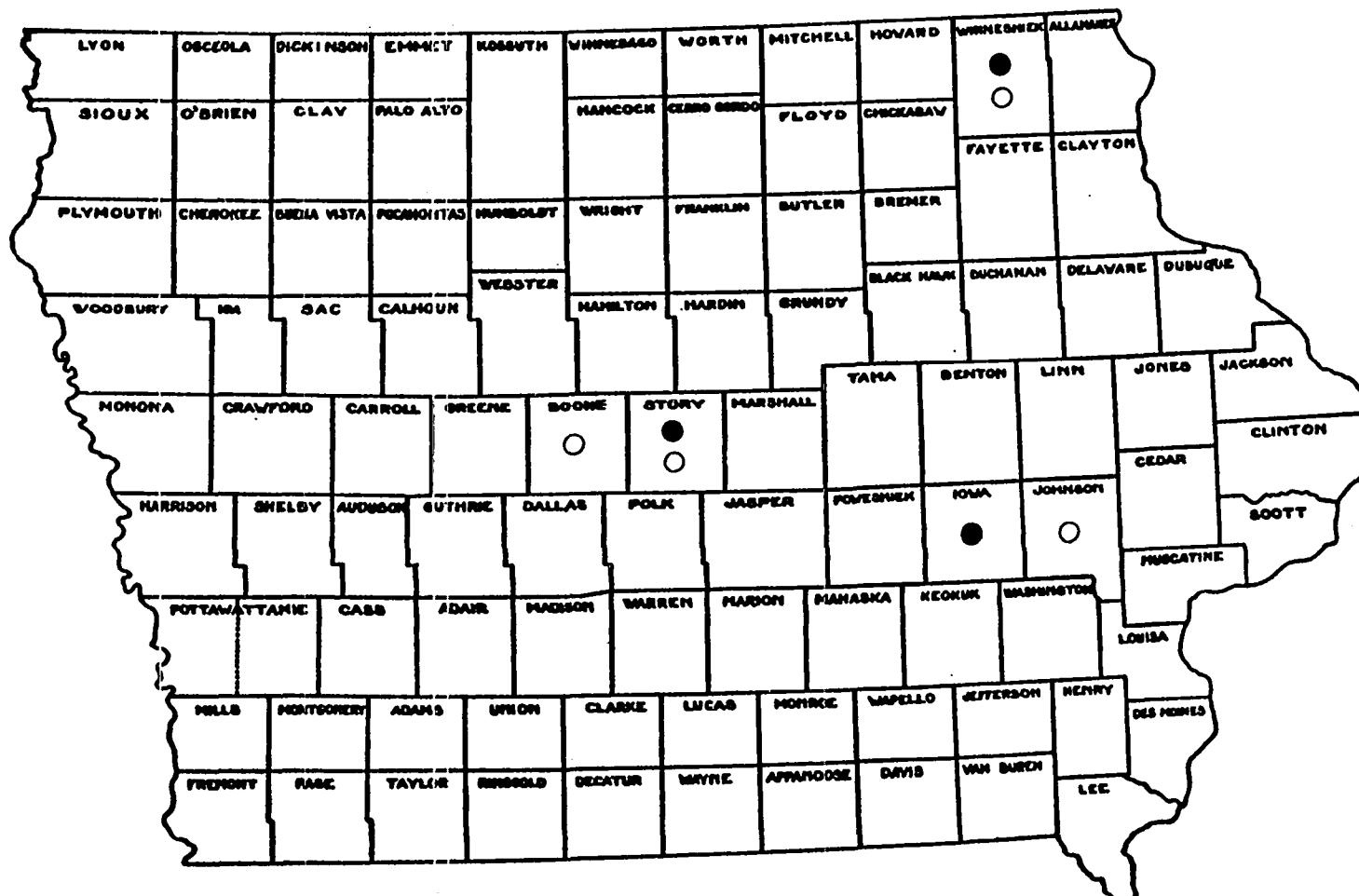


Figure 35. Distribution of Sclerotinia tuberosa ([Hedwig] Fries) Fuckel in Iowa

Ciboria pseudotuberosa Rehm

Apothecia arising from a sclerotium-like growth within the seeds of the host (Quercus spp.), at first cup-shaped becoming discoid or umbilicate at maturity, brownish, 1-2 cm in diameter; stalk variable in length, 5-20 mm, darker than cup; ascus cylindric, 110-150 x 6-10 μ m, uniseriate; ascospores elliptical with slightly pointed ends, 8-10 x 4-6 μ m, paraphyses filiform, slightly enlarged above, 2-3 μ m in diameter.

On cotyledons of old acorns, Quercus spp.; fall (August). Not common.

Distribution (Figure 36) Johnson: UI 1936; Story: ISU (no date), RDJ 1973; Winneshiek: ISU 1882.

Monilina fructicola (Wint.) Honey, the cause of brown-rot of fruits, may produce several to many apothecia in each overwintered, mummified fruit during April or May (Figure 38). The apothecia are similar in color but slightly larger than Sclerotinia tuberosa. A conidial (asexual) stage commonly occurs in the life cycle of M. fructicola. Herbarium and/or teaching collection specimens of the sexual stage are known only for two Iowa counties (Johnson: UI 1940, 1943, 1955; Story: ISU late 1950's). This fungus probably occurs throughout Iowa especially in orchards and areas where Prunus americana (wild plum) grows. However, no fresh specimens were seen or collected during this study.

Stromatinia smilacinae (Durand) Whetzel (Figure 41)

Apothecium similar to Sclerotinia tuberosa except it is slightly larger, campanulate with a depression in the center at maturity and darker brown; small sclerotia, 1-2 mm in diameter, are present in the host tissue (Smilacina racemosa [L.] Desf.) but do not give rise to the apothecia;

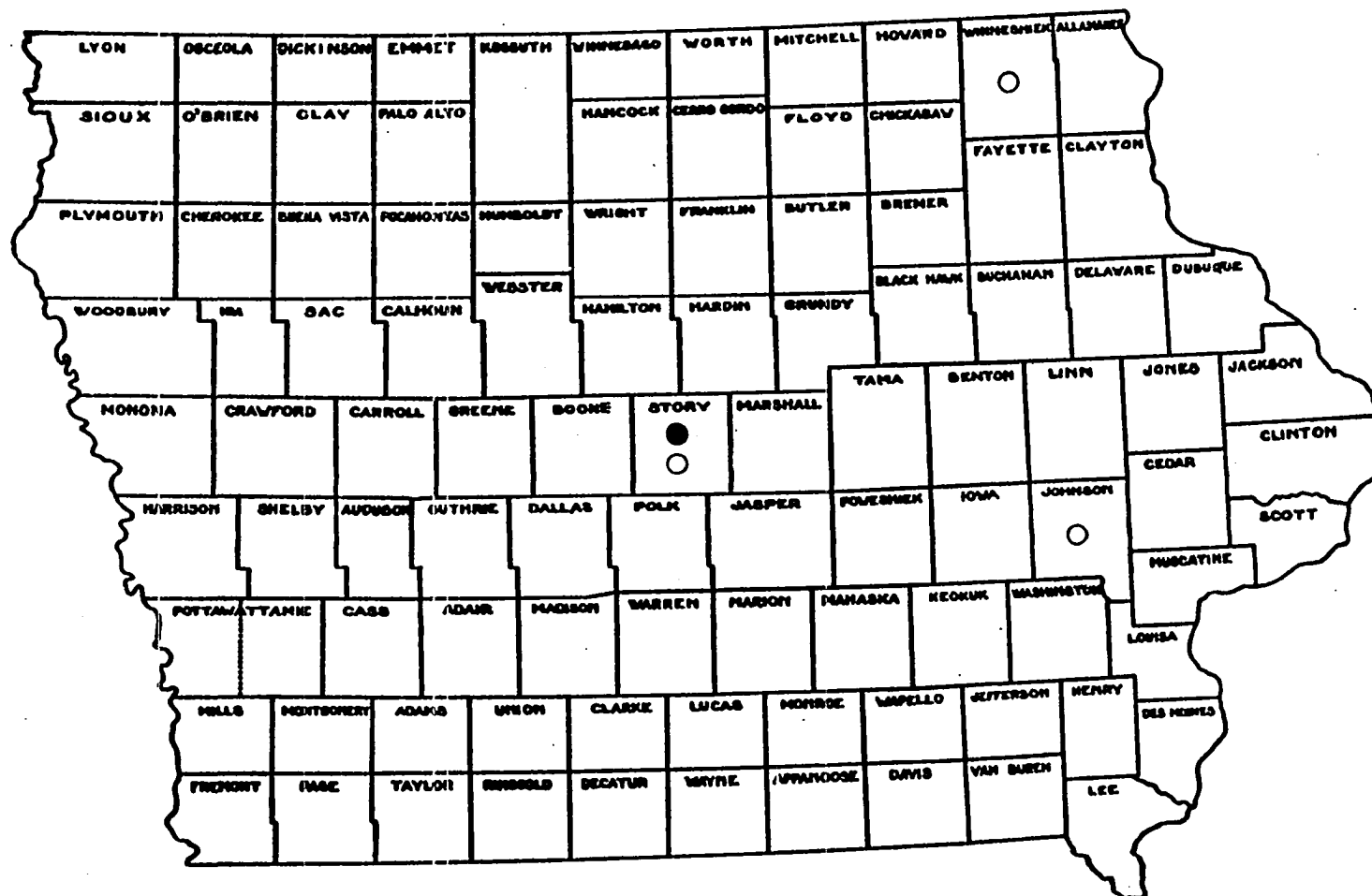


Figure 36. Distribution of Ciboria pseudotuberosa Rehm in Iowa

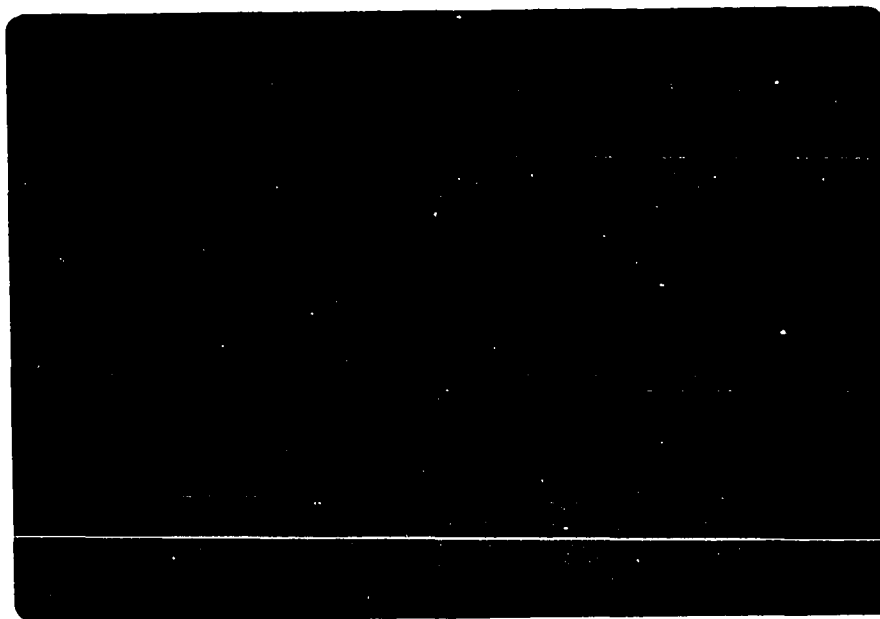


Figure 37. Sclerotinia tuberosa

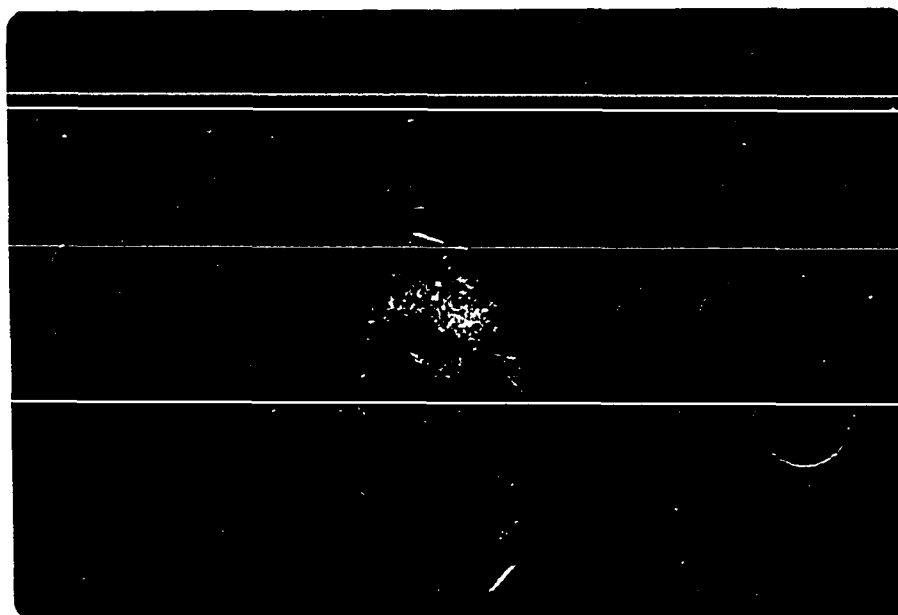


Figure 38. Monilinia fructicola

ascospores hyaline, nonseptate, smooth, narrowly ellipsoid, 12-15 x 4-5 μ m.

In wooded areas on dead rhizomes of Smilacina racemosa; spring (April-May). Not common.

Distribution (Figure 39)

Story: ISU 1950, RDJ (1973), 1975.

Rutstroemia Karsten

Apothecia usually arising from stromatized parts of the host tissue; stromata present in most species, either blackened or delimited by a black line; apothecia cup-shaped, waxy-coriaceous, stalked; asci 8-spored; ascospores hyaline, usually 1-5 septate.

Rutstroemia macrospora (Peck) Kanouse (Figure 42)

Apothecia solitary or sometimes gregarious, 5-15 mm in diameter, cinerous to brownish, becoming darker with age, usually discoid at maturity; stalk 1-1.5 cm in length; presence of stroma doubtful; asci cylindric or clavate, 150-180 x 10-15 μ m, 8-spored; ascospores uniseriate, narrow ellipsoid or fusoid, straight or slightly curved, hyaline, 22-35 x 6-8 μ m, becoming 1-5 septate at maturity; paraphyses filiform 2-3 μ m in diameter.

On decaying wood of broadleaved trees; summer, fall (July-September). Common.

Distribution (Figure 40)

Allamakee: RDJ 1973; Boone: RDJ 1973, (1974); Clayton: RDJ 1973; Decatur: RDJ 1973; Delaware: RDJ 1973; Dickinson: UI 1926 (as Geopyxis nebulosa Cooke), RDJ 1974; Dubuque: RDJ 1973, 1974, (1975); Fremont: RDJ 1974; Hancock: ISU (1962); Iowa: RDJ 1974; Johnson: UI 1924, 1926 (both as G. nebulosa); Ringgold: RDJ 1973; Story: RDJ 1973; Webster: RDJ 1973, (1974).

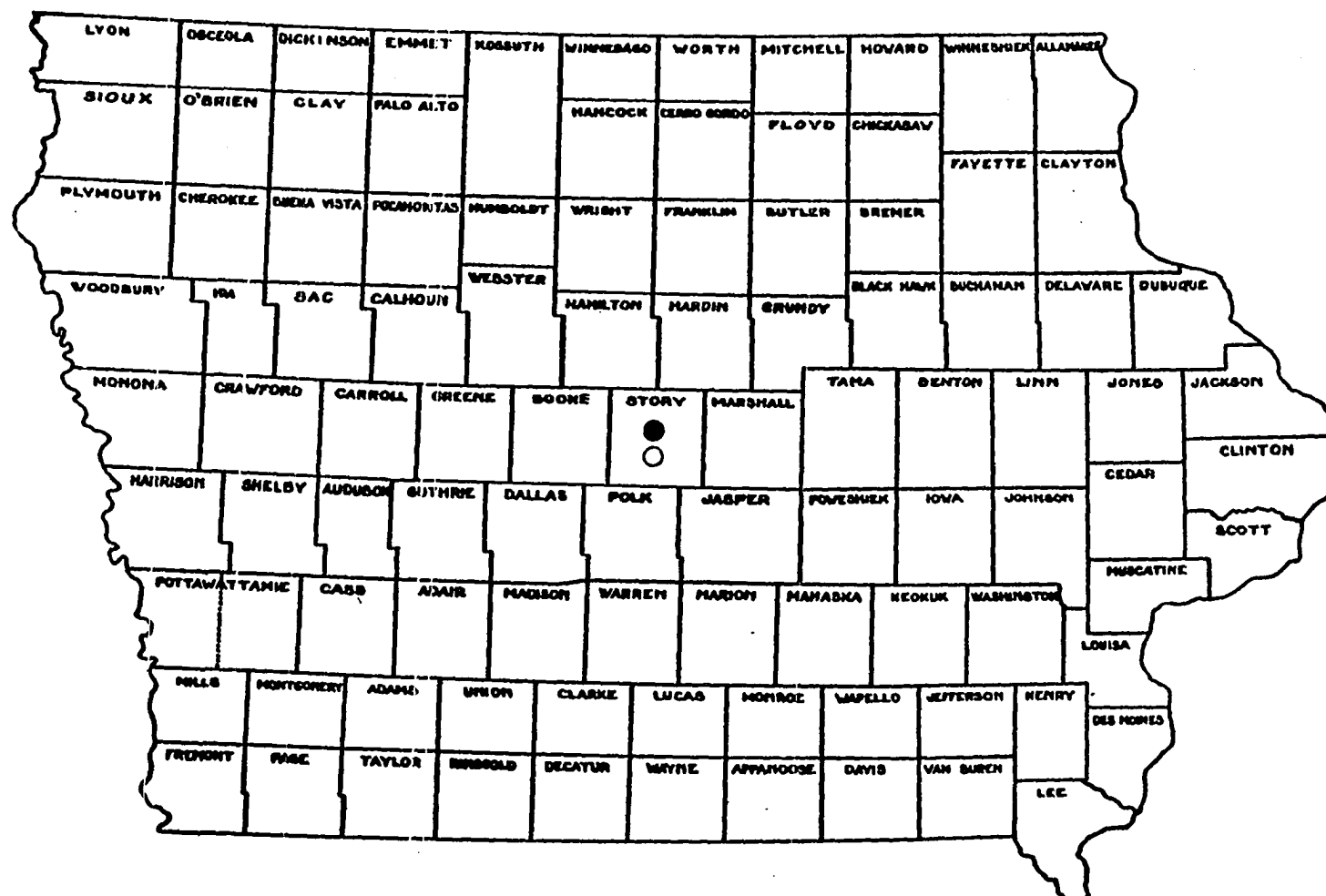


Figure 39. Distribution of Stromatinia smilacinae (Durand) Whetzel in Iowa

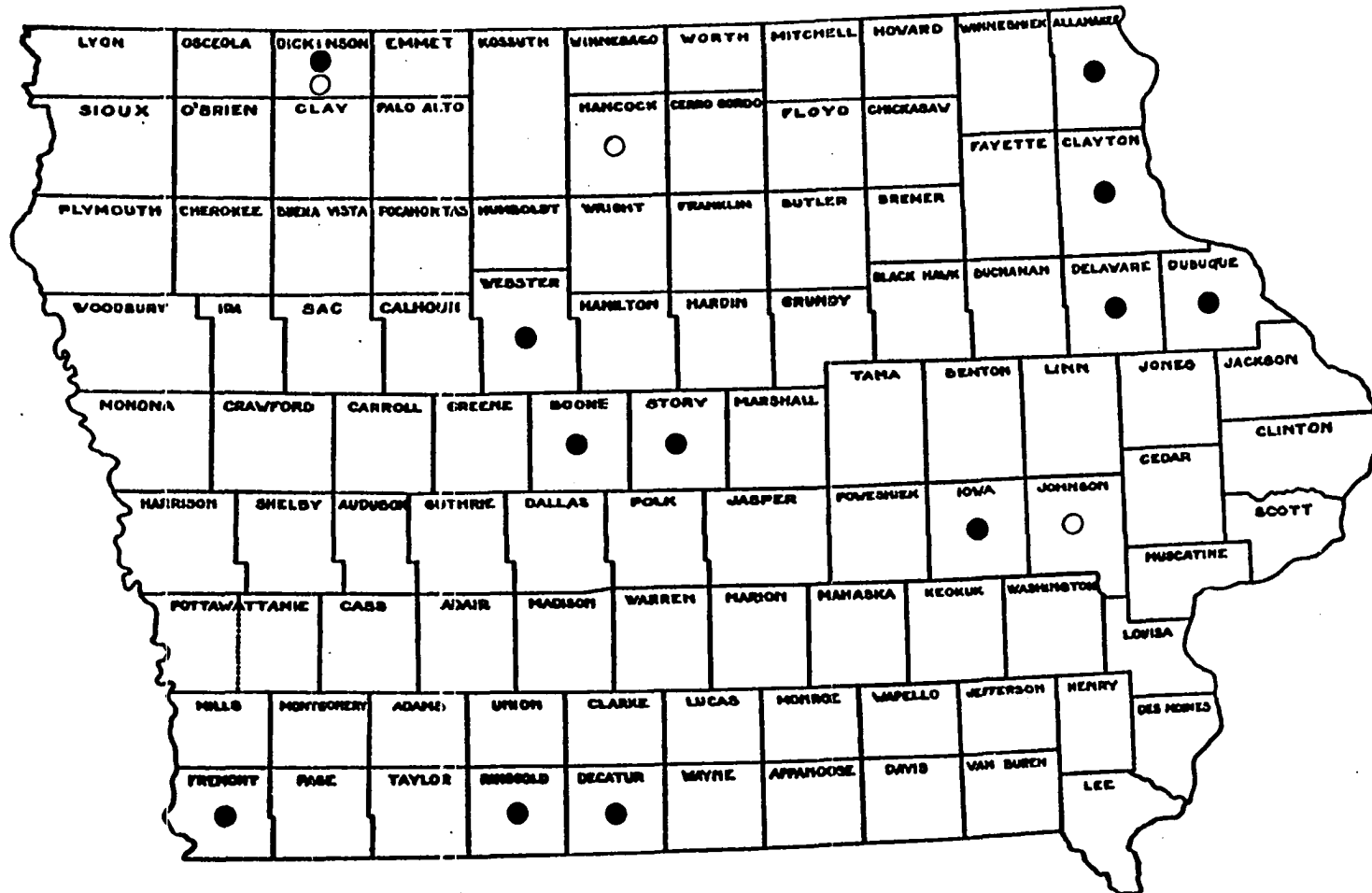


Figure 40. Distribution of Rutstroemia macrospora (Peck) Kanouse in Iowa

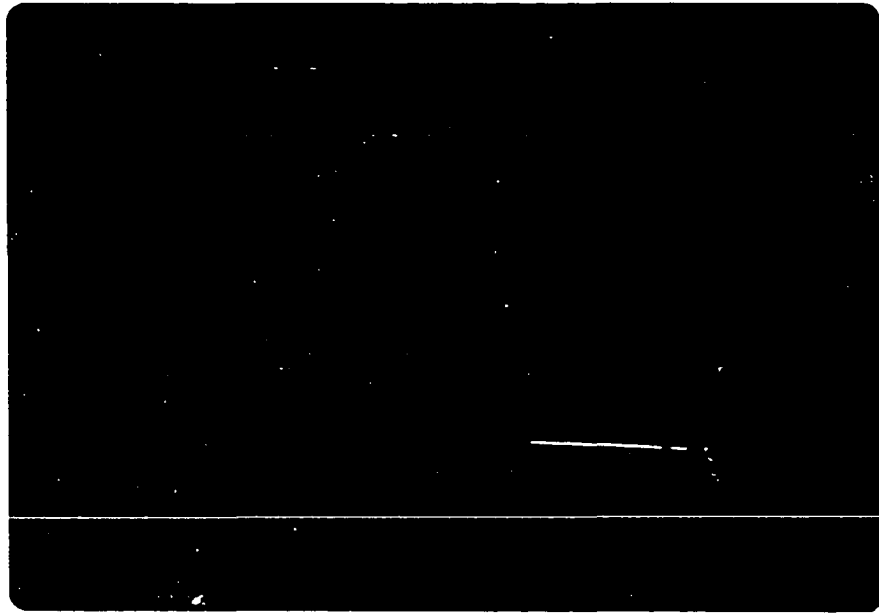


Figure 41. Stromatinia smilacinae

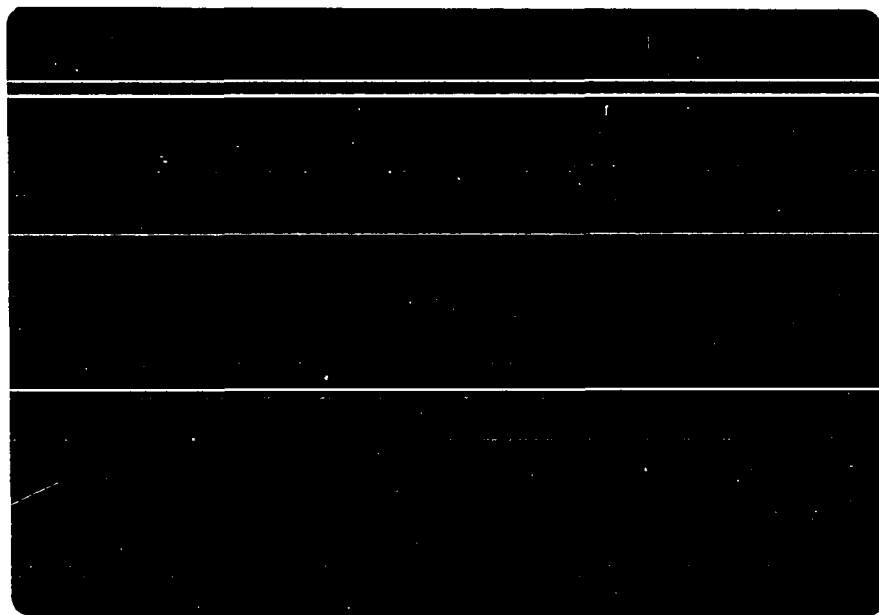


Figure 42. Rutstroemia macrospora

Rutstroemia firma (Persoon) Karsten

Apothecia solitary or sometimes gregarious, on decorticated twigs with a blackened stromatic surface; apothecia infundibuliform at first, becoming discoid with age, hymenium brown, darker than the excipulum; stalk 5-15 mm in length; asci cylindric or subcylindric, 130-150 x 9-12 μm , 8-spored; ascospores uniseriate, hyaline, narrow ellipsoid to fusoid and slightly inequilateral, 14-19 x 4-6 μm , becoming 3-5 septate at maturity; paraphyses filiform, brown, enlarged somewhat at apices, reaching a diameter of 2-3 μm .

On fallen twigs of broadleaved trees; summer, fall (August-September). Fairly common.

Distribution (Figure 43) Allamakee: RDJ 1973; Clayton: RDJ 1973; Dubuque: RDJ 1973; Story: RDJ 1973, 1974.

Rutstroemia longipes (Cooke and Peck) White

Apothecia solitary but several often arising from each stroma, the stroma occurring on the petioles of fallen leaves; apothecia discoid at maturity, yellowish, 1-5 mm in diameter; stalk variable in length, often 3-20 mm long; asci cylindric-clavate 80-130 x 8-12 μm ; ascospores uniseriate, elliptical to somewhat fusoid and slightly inequilateral, 10-14 x 4-6 μm , often containing 2 oil drops, sometimes becoming 1-3 septate at maturity; paraphyses filiform.

In wooded areas of petioles of decaying leaves, especially Fraxinus spp.; fall (August). Not common.

Distribution (Figure 44) Dickinson: ISU 1968 or 1970; Fremont: RDJ 1973; Story: RDJ 1973.

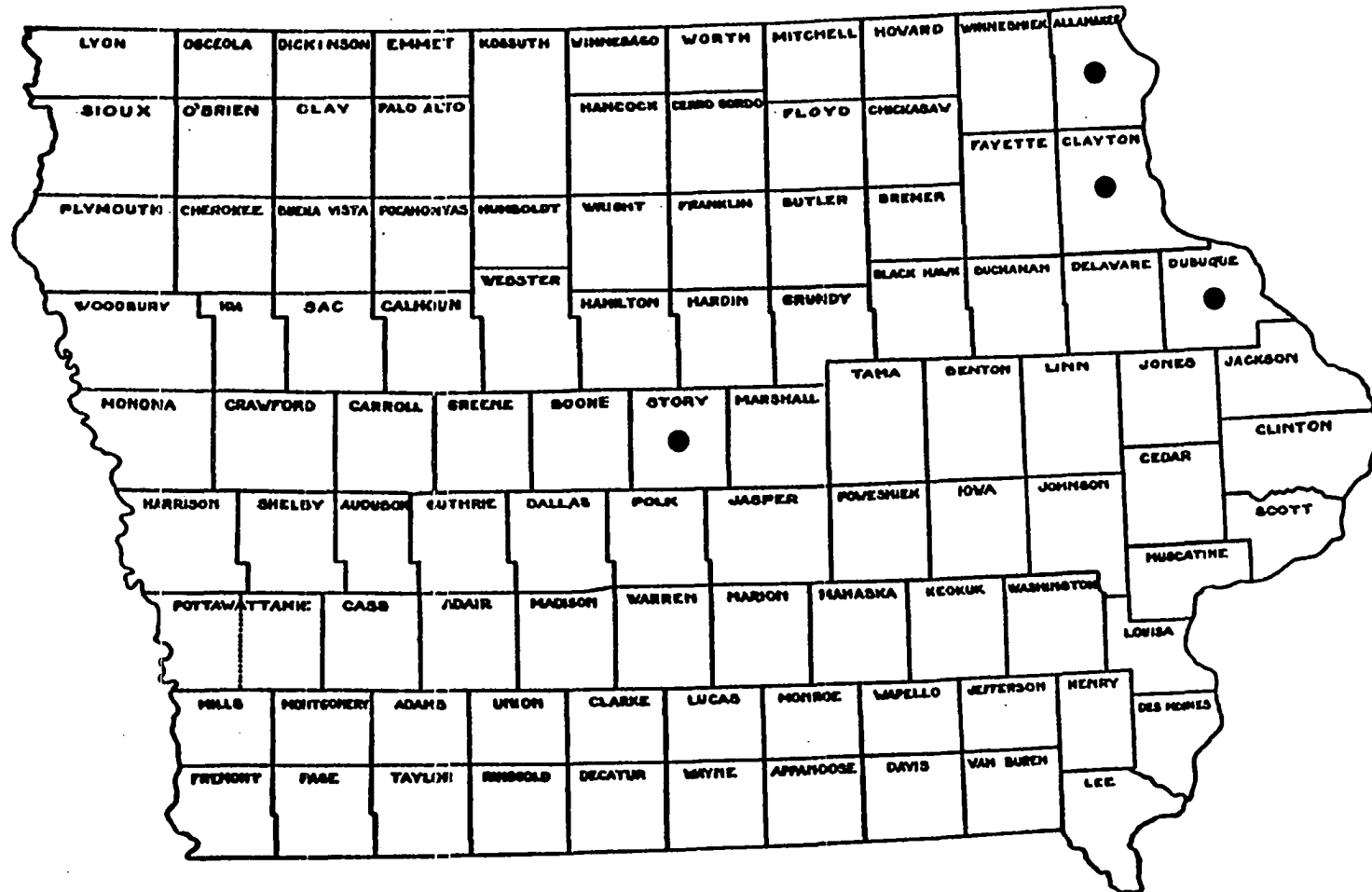


Figure 43. Distribution of *Rutstroemia firma* (Persoon ex Fries) Karsten in Iowa

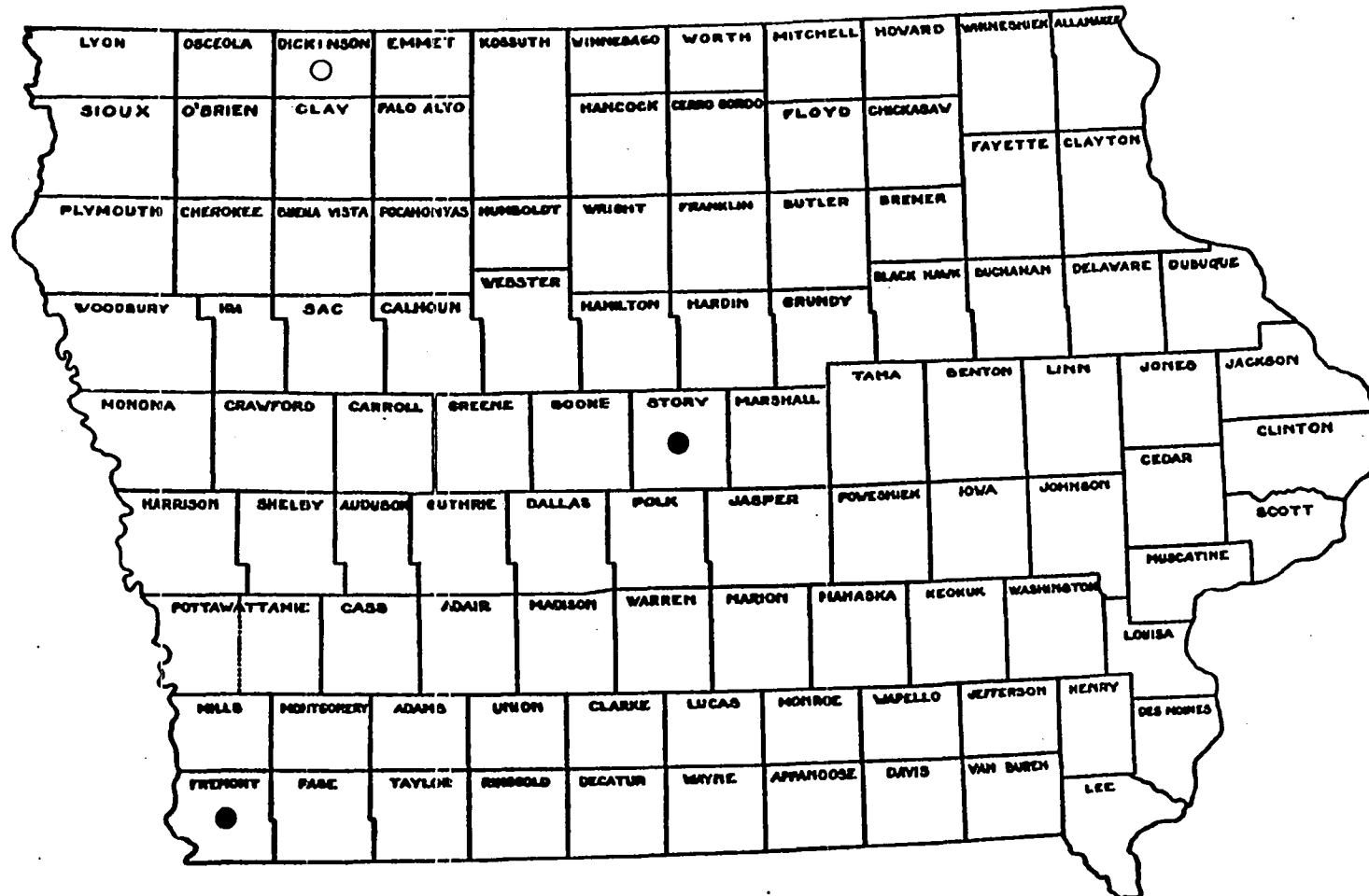


Figure 44. Distribution of Rutstroemia longipes (Cook and Peck) White in Iowa

Helotiaceae

Apothecia may be stalked or sessile and range in size from approximately 1 mm to several centimeters in diameter; color tends to be light or bright colored but may be dark; texture ranges from soft and fleshy to waxy to leathery, excipulum either with outer layers composed of parallel hyphae (a *textura intricata* to *textura prismatica*) or a thin layer of short, cuboid or globose cells covering a thicker layer of woven hyphae; asci inoperculate, usually 8-spored; ascospores usually hyaline but variable in size and septation; for convenience this heterogenous family is often divided into subunits called tribes.

Key to genera and species in Iowa

1. Apothecia purplish, blue-green or olive-green; 5-30 mm in diameter, growing on rotting wood, ascospores not in fascicles or filiform..... 2
2. Apothecia greenish..... Chlorosplenium.. 3
 3. Apothecia blue-green, up to 5 mm in diameter, wood stained blue-green by mycelium; ascospores 6-10 x 1.2-2 μ m.....
..... C. aeruginascens
 3. Apothecia light green or olivaceous, 1-3 cm in diameter; wood not stained green; ascospores 9-14 x 3-4 μ m.....
..... C. versiforme
2. Apothecia purplish..... Coryne.. 4
 4. Apothecia 20-30 mm in diameter, ascospores 24-30 x 5-7 μ m....
..... C. urnalis
 4. Apothecia smaller, 2-20 mm in diameter, ascospores 10-19 x 4-6 μ m..... C. sarcoides

1. Apothecia some other color; if greenish, then greenish-black; growing on wood or other plant tissue; spores elliptical to fusoid or filiform..... 5
5. Ascospores filiform, in fascicles, many septate, 30-75 μm long, apothecia greenish black..... Holwaya gigantea
5. Ascospores elliptical to fusoid, usually less than 20 μm long....
..... Helotium.. 6
6. Ascospores usually 15 μm or longer, on petioles or fruits.... 7
7. Apothecia growing on petioles, ascospores 16-20 μm long..
..... H. fraternum
7. Apothecia on acorns and hickory-nut husks, ascospores
13-21 μm long..... H. fructigenum
6. Ascospores usually less than 15 μm long; apothecia on
decaying wood..... 8
8. Apothecia 1-4 mm in diameter, lemon yellow. H. citrinum
8. Apothecia 1-4 cm in diameter, excipulum dark brown,
hymenium black..... Phaeobulgaria inquilans

Chlorosplenium Fries

Apothecia stipitate, or substipitate, often reaching a diameter of 1 cm, green or olivaceous; asci 8-spored; ascospores hyaline, nonseptate; paraphyses slender, clavate, growing on rotting wood.

Chlorosplenium versiforme (Persoon ex Fries) De Not.

Apothecia scattered or in small clusters, more or less cup-shaped at first, becoming expanded and subdiscoid, or more often elongated on one

side, entirely light-green or olivaceous, occasionally darker, 1-3 cm diameter; stem short, 4-5 mm long; asci cylindric-clavate, 80-100 x 5-7 μm , 8-spored; ascospores uniseriate to biseriate, cylindrical with rounded ends, straight or slightly curved, 9-14 x 3-4 μm , occasionally 1-septate; paraphyses enlarged above reaching a diameter of 2-3 μm .

On decaying wood; summer (August). Not common.

Distribution (Figure 45) Allamakee: RDJ 1974; Webster: RDJ 1973; Winneshiek: ISU (no date).

Chlorosplenium aeruginascens (Nyl.) Karsten is similar to C. versiforme except that the apothecia are smaller and blue-green, the ascospores are smaller, 6-10 x 1.2-2 μm , and the wood on which the mycelium grows is stained blue-green (Figure 51). Its distribution is Boone?: ISU (no date); Dickinson: UI 1929; Emmet: ISU 1972; Iowa: ISU 1972; Johnson: UI (no date), 1905; Webster: ISU 1971; Winneshiek: ISU (no date).

Coryne Tulsane

Apothecia usually clustered, gelatinous, purple, asci 8-spored, ascospores fusoid, becoming septate, hyaline, paraphyses filiform; conidial and sexual fruiting bodies produced on the same base.

Coryne urnalis (Nyl.) Sacc.

Apothecia short stalked, or sessile, usually clustered, gelatinous, reddish-purple to purple, concave or flattened to repand with age, often irregular and lobed, 2-3 cm in diameter; asci cylindric-clavate, 160-190 x 10-15 μm , 8-spored; ascospores biseriate, elongate-fusoid to inequilateral, 24-30 x 5-7 μm , becoming 1-9 septate; paraphyses filiform, slightly enlarged above.

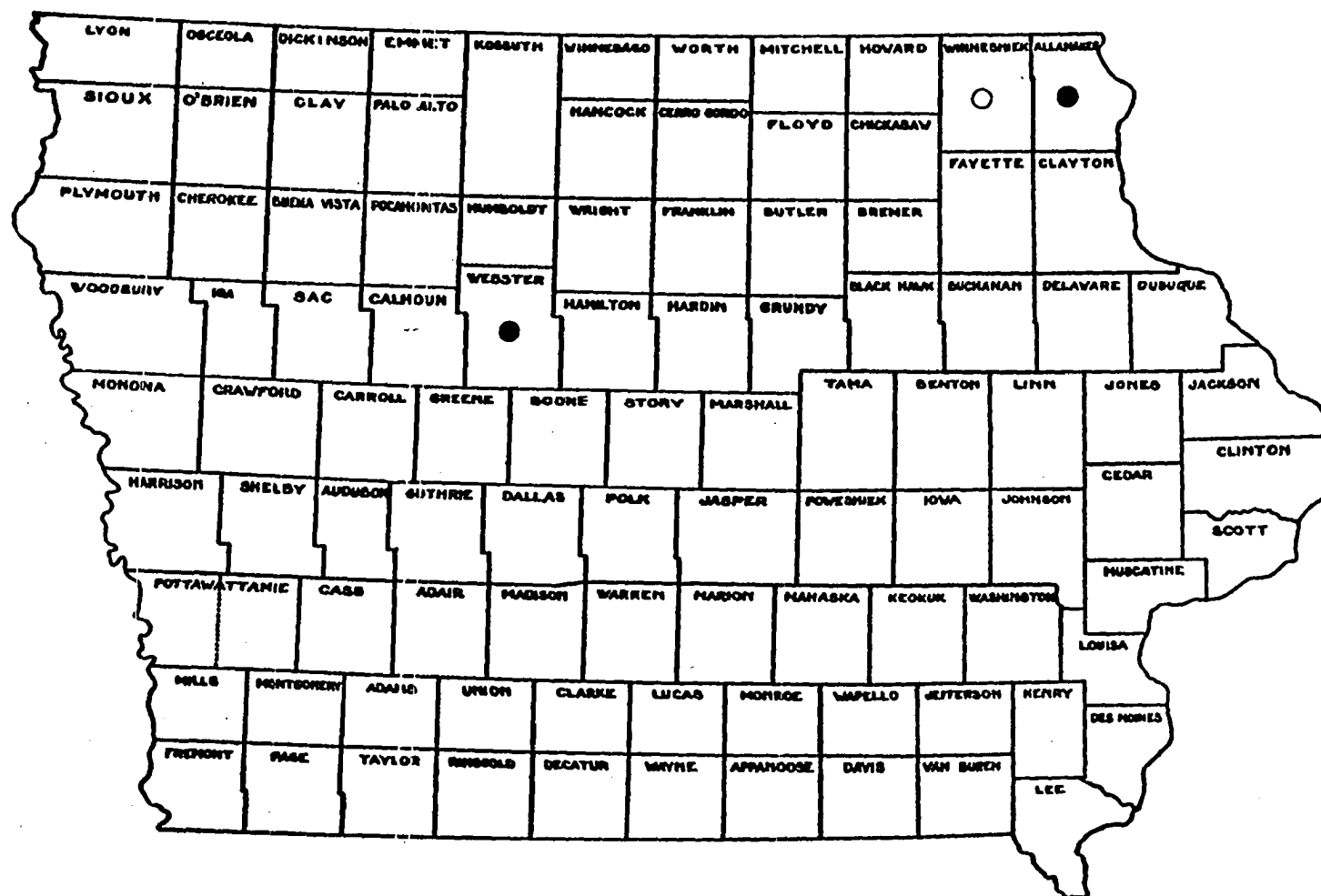


Figure 45. Distribution of *Chlorosplenium versiforme* (Persoon ex Fries) De Not. in Iowa

On rotten wood of various kinds; fall (September-November). Fairly common.

Distribution (Figure 46) Allamakee: RDJ 1974; Dubuque: RDJ 1973; Hancock: RDJ 1974; Johnson: UI 1924, 1932, 1936, 1948; Lucas: RDJ 1974; Linn: RDJ 1974; Story: RDJ 1974; Webster: RDJ 1974.

Coryne sarcoides (Jac. ex Gray) Tulsane

Similar to C. urnalis; differing only in size of the apothecia, 2-10 mm in diameter, smaller asci, 100-135 x 7-8 μ m and ascospores 10-19 x 4-6 μ m, often several septate.

On rotten wood; fall (September-October). Not common.

Distribution (Figure 47) Dubuque: UI 1928, RDJ 1973; Johnson: UI 1902, 1904, 1923, 1924; Muscatine: UI 1928.

Holwaya gigantea (Peck) Durand

Apothecia single or scattered, cup-shaped at first, becoming discoid to plane at maturity, 3-15 mm in diameter, greenish-black, usually more blackish, fleshy-gelatinous, hymenium and excipulum concolorous; stalk 2-5 mm in length, tapering upwards, often with a greenish-brown pubescence which often disappears with age; asci narrowly clavate, 120-200 x 9-12 μ m; ascospores biseriate, more or less fasciculate, filiform-cylindric, with ends usually rounded or one end occasionally acute, straight or curved, hyaline, 14-20 septate, 30-37 x 3-5 μ m; paraphyses filiform, longer than asci, globose at their apices where they reach a diameter of 4-5 μ m.

Conidial form often present at same time as sexual form. Conidial structure blackish, with a tapering stalk, 3-4(-10) x 1-2 μ m, and an ellipsoid, soft viscid head 2-6 x 2-4 μ m; conidia hyaline, ellipsoid, 3 x 1 μ m.

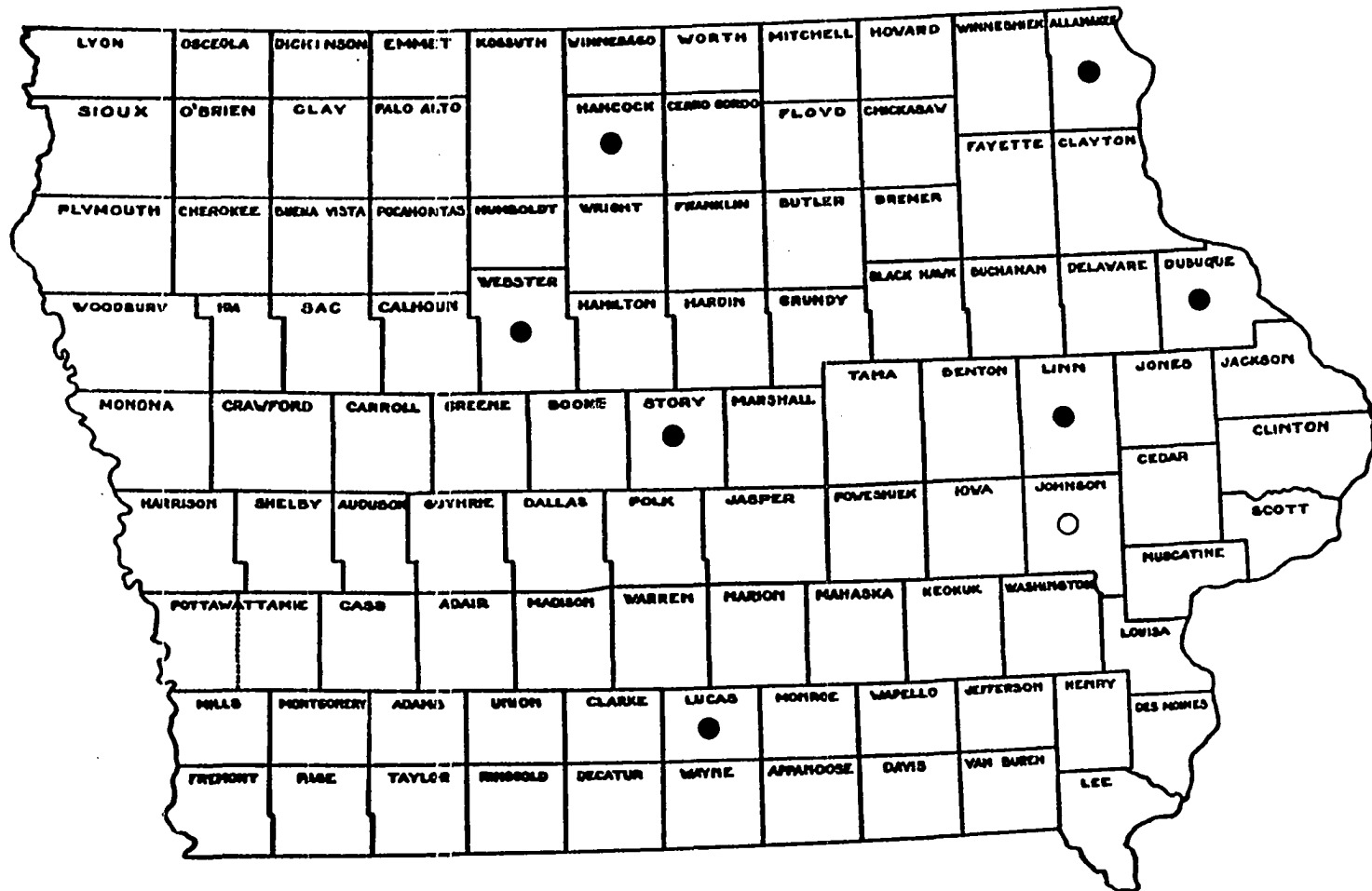


Figure 46. Distribution of *Coryne urnalis* (Nyl.) Sacc. in Iowa

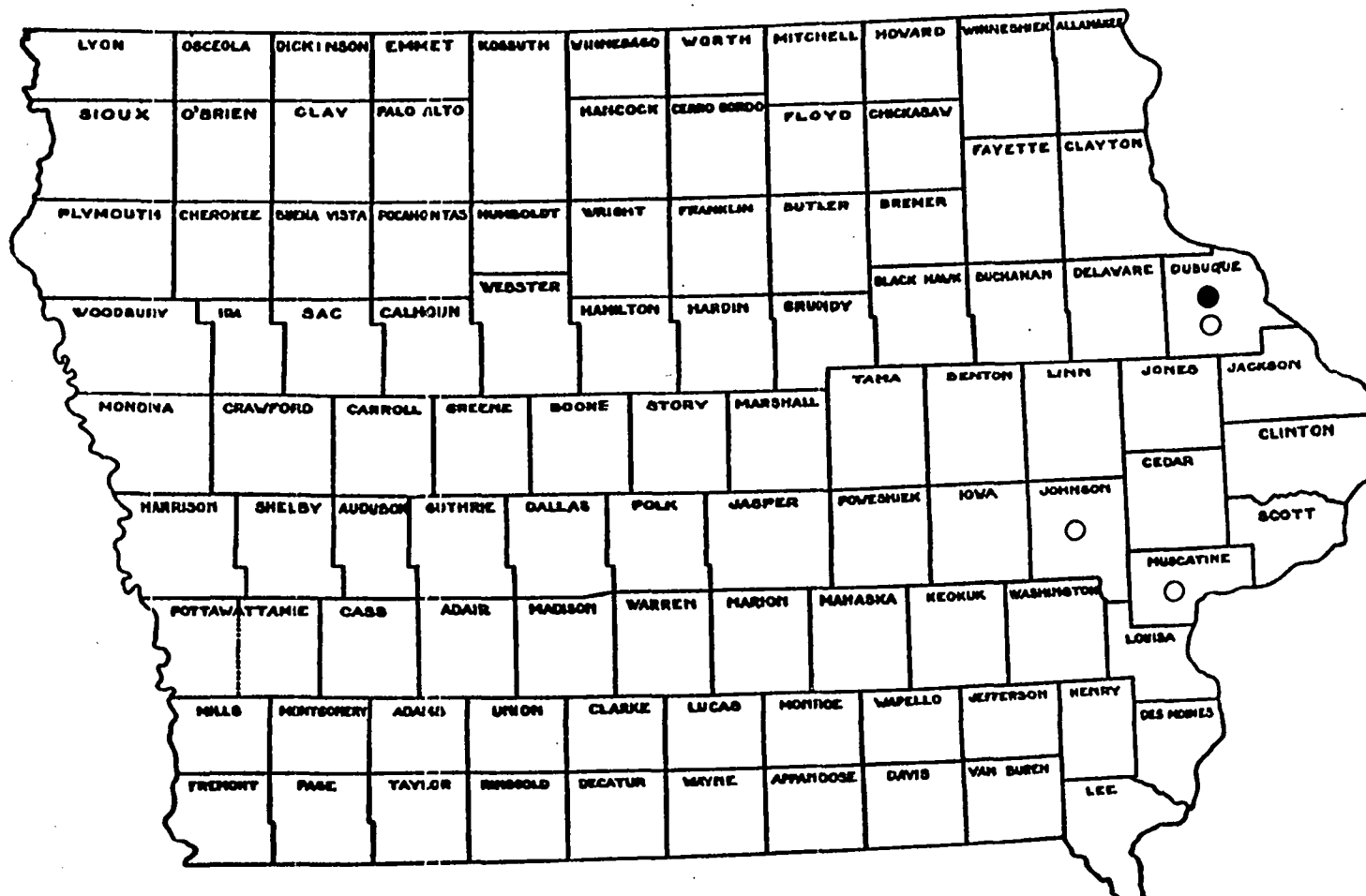


Figure 47. Distribution of *Coryne sarcoides* (Jac. ex Gray) Tulsane in Iowa

On rotten logs of various kinds; fall (October). Not common.

Distribution (Figure 48) Linn: RDJ 1974.

Helotium Fries

Apothecia usually small (not exceeding 2-3 mm in diameter), long stipitate to sessile, excipulum glabrous, color variable but tending to be bright-colored; asci 8-spored; ascospores nonseptate, or occasionally spuriously septate, ellipsoid, fusoid, or allantoid, hyaline or subhyaline; paraphyses filiform.

Because of the diversity of characteristics in this genus, various authors have divided this genus into several genera. Since there seems to be little agreement between authors, Seaver's treatment (1951) of this genus has been followed here.

Helotium fraternum Peck

Apothecia solitary or scattered on the same substrate, 1-2 mm in diameter, cup-shaped becoming disk-shaped or plane at maturity, whitish to yellowish, darker with drying; asci clavate-cylindric, 70-100 x 8-12 μ m, 8-spored; ascospores uniseriate to biseriate; elongate-fusiform, often slightly curved, rounded at one or both ends, usually with an oil drop in either end, 16-20 x 4-5 μ m; paraphyses filiform, 1 μ m wide.

On decaying petioles of leaves, usually Acer spp.; late summer, fall (August-October). Fairly common.

Distribution (Figure 49) Allamakee: RDJ 1973; Delaware: RDJ 1973; Dubuque: RDJ 1973; Linn: RDJ 1974; Story: RDJ 1974.

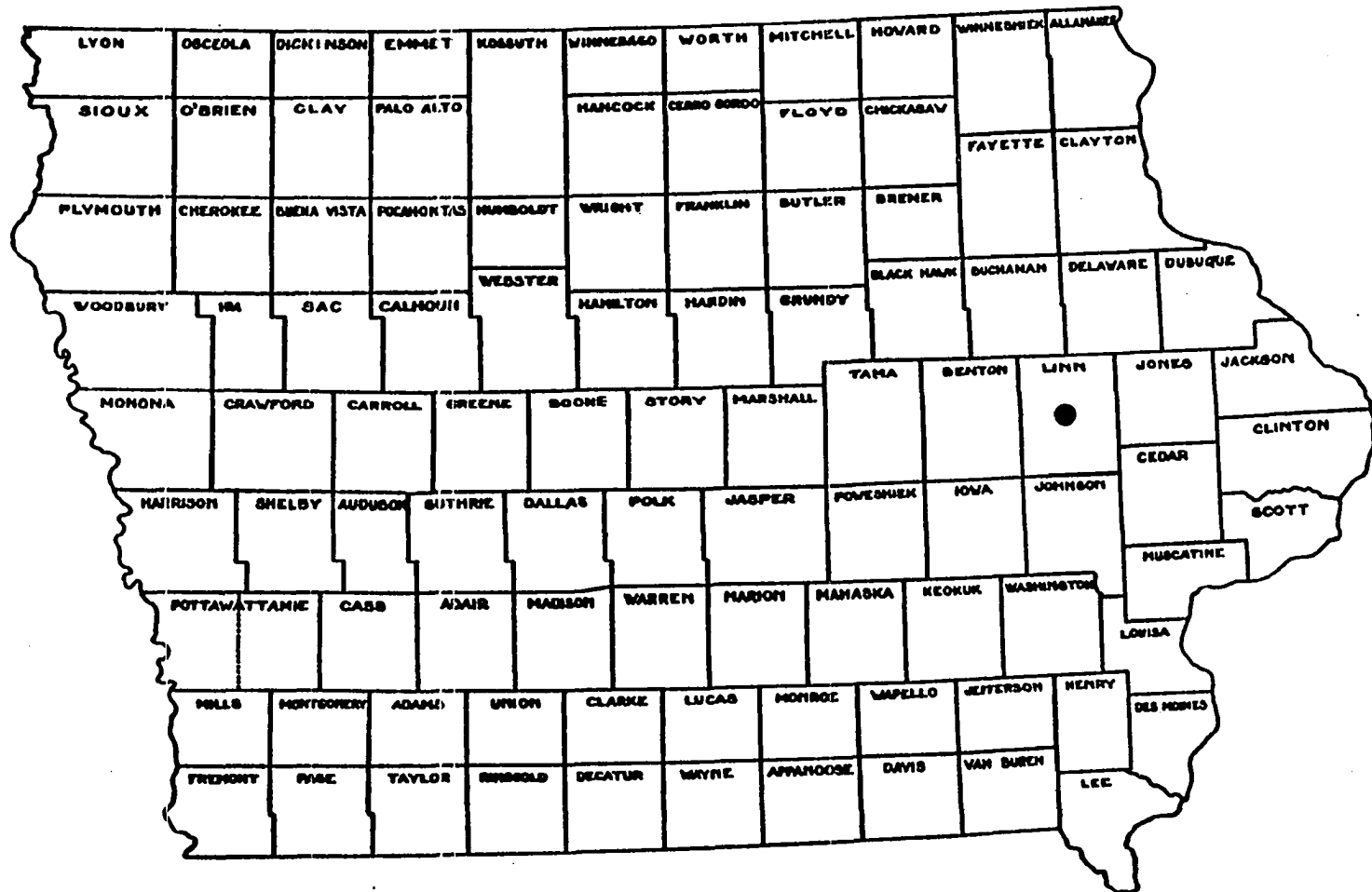


Figure 48. Distribution of *Holwaya gigantea* (Peck) Durand in Iowa

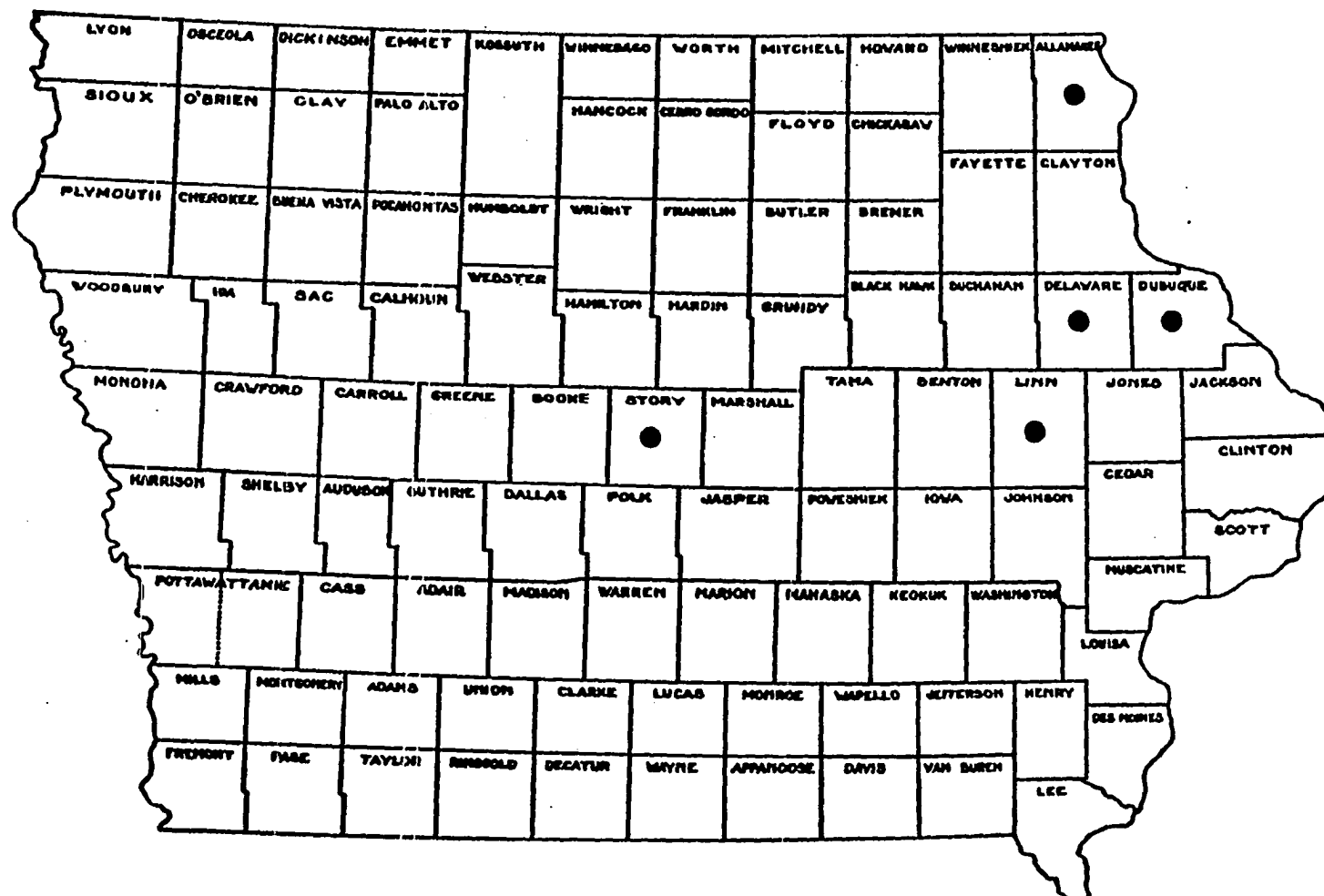


Figure 49. Distribution of *Helotium fraterum* Peck. in Iowa

Helotium fructigenum (Bull.) Karsten (Figure 52)

Apothecia solitary or gregarious, cup-shaped at first, becoming plane or nearly so, reaching a diameter of 1-4 mm, hymenium pale yellow; stalk cream-colored, slender, 2-10 mm long; asci cylindric-clavate, 80-100 x 7-9 μ m, 8-spored; ascospores uniseriate to biseriate, oblong-fusiform or slightly inequilateral, 13-21 x 3-4 μ m, often with two oil drops and numerous smaller ones; paraphyses filiform, slightly enlarged above, reaching a diameter of 3 μ m.

On acorns and hickory nut husks; late summer, fall (August-October). Fairly common.

Distribution (Figure 50) Allamakee: RDJ 1973; Boone: RDJ 1974; Clayton: RDJ 1973; Delaware: RDJ 1973; Dubuque: RDJ 1973, 1974; Fremont: RDJ 1974; Guthrie: RDJ 1975; Hancock: ISU (1962), RDJ 1974; Iowa: ISU (1963); Linn: RDJ 1974; Story: RDJ 1973, (1974); Webster: RDJ 1973.

Helotium citrinum (Hedw.) Fries (Figure 54)

Apothecia gregarious, often forming large confluent masses, shallow cup-shaped, 1-4 mm in diameter, hymenium plane or nearly so, lemon yellow; stalk short, up to 1 mm in length, lighter yellow than hymenium; asci cylindric-clavate, 100-135 x 10 μ m; 8-spored; ascospores biseriate, ellipsoid or fusoid, with oil drops at each end, 9-14 x 3-5 μ m, occasionally 1-septate; paraphyses filiform, slightly enlarged upwards.

On decaying wood; summer, fall (July-November). Common.

Distribution (Figure 53) Allamakee: ISU (1964), RDJ 1973, (1974); Boone: RDJ 1974; Clayton: RDJ 1973; Dubuque: ISU (1962), RDJ 1973, 1974; Emmet: RDJ 1974; Fremont: RDJ 1973, (1974); Guthrie: RDJ 1975; Hancock:

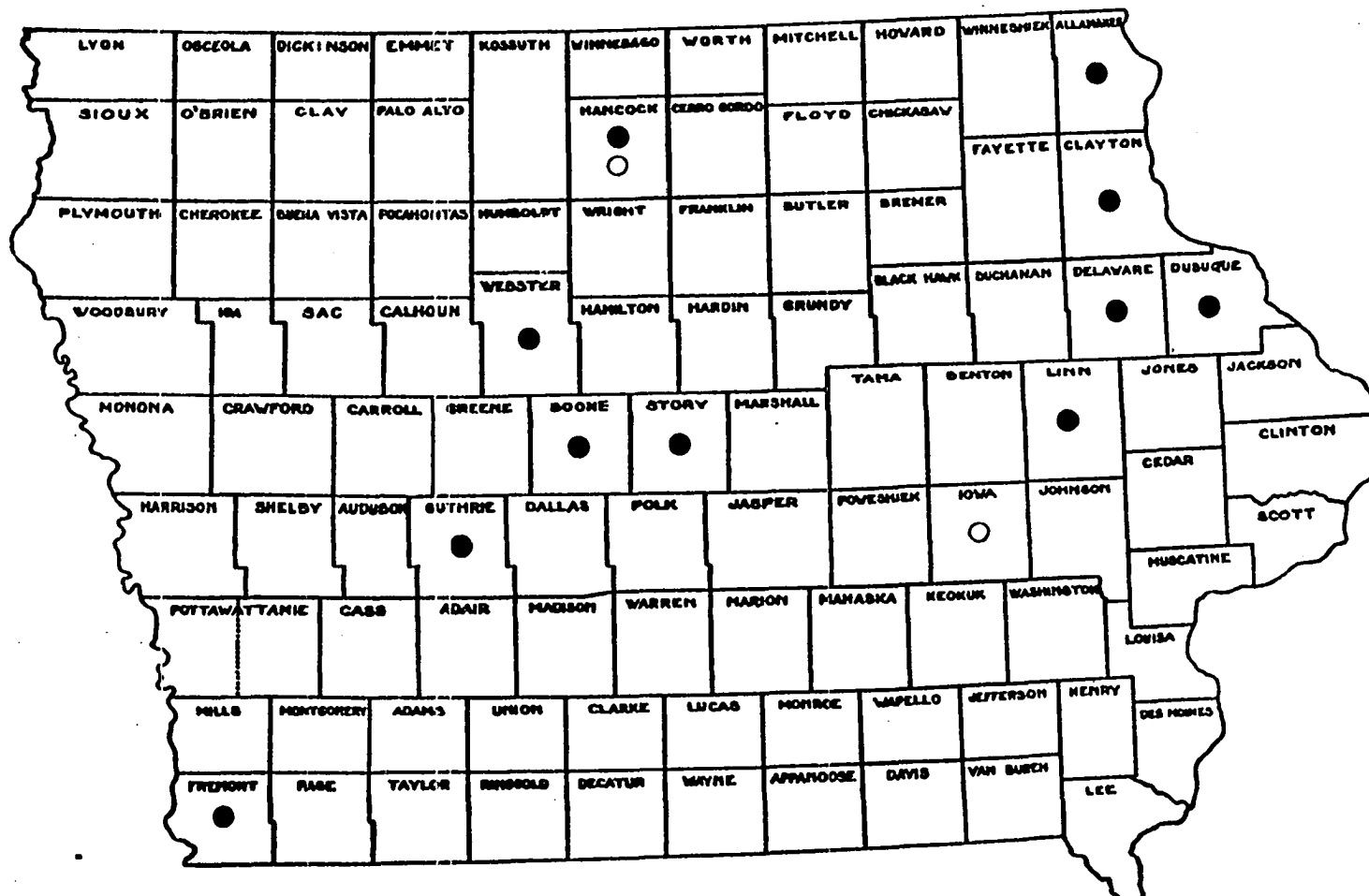


Figure 50. Distribution of Helotium fructigenum (Bull.) Karsten in Iowa



Figure 51. Chlorosplenium aeruginascens

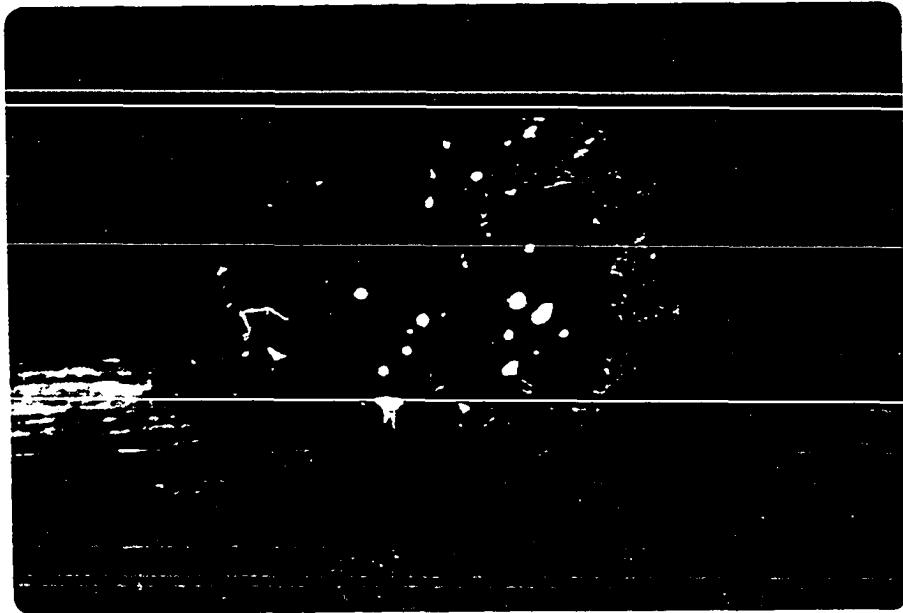


Figure 52. Helotium fructigenum

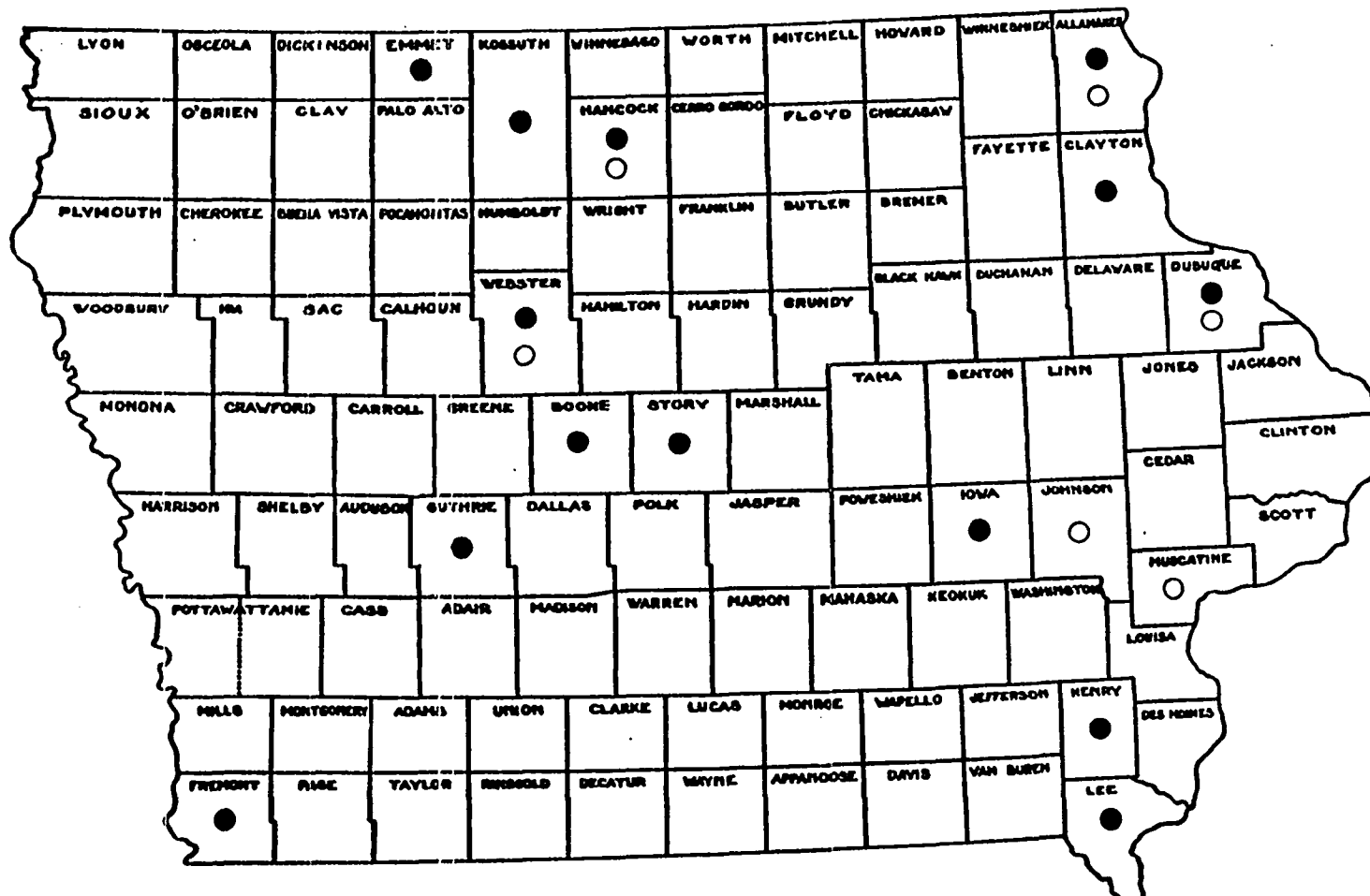


Figure 53. Distribution of Helotium citrinum (Hedw.) Fries in Iowa

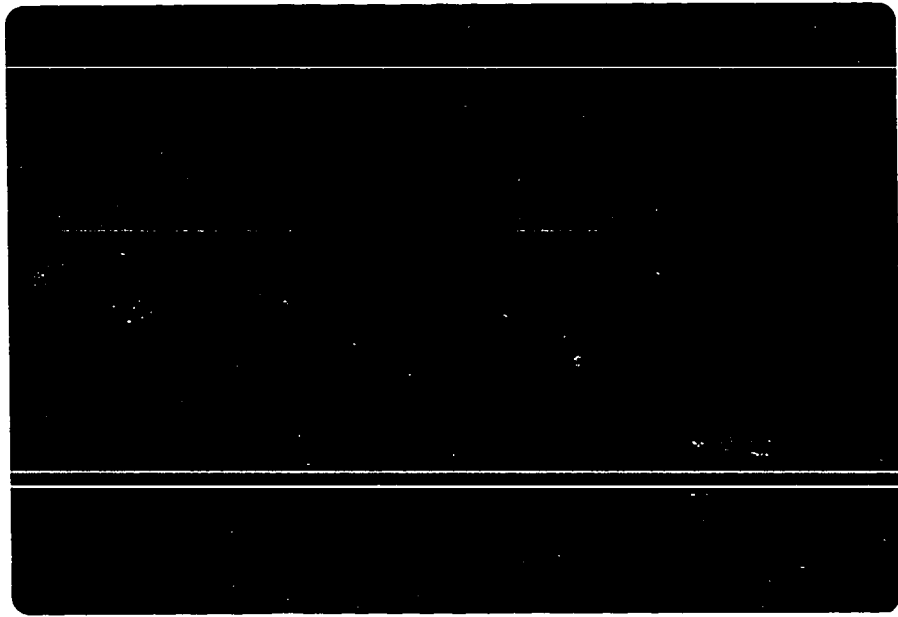


Figure 54. Helotium citrinum

ISU (1970), RDJ 1974; Henry: RDJ 1973; Iowa: RDJ 1974; Johnson: UI 1904, 1920, 1923, 1925, 1928, 1948; Kossuth: RDJ 1974; Lee: RDJ 1974; Linn: RDJ 1974; Muscatine: UI 1900; Story: RDJ 1973, (1974); Webster: ISU (1962), RDJ 1973, 1974.

Phaeobulgaria inquilans (Pers.) Nannf.

Apothecia occurring singly or often in clusters with several apothecia having a common base, turbinate, gelatinous (similar to Bulgaria rufa); stalk short, usually less than 1 cm, apothecia often appearing sessile; hymenium concave at first, becoming convex with age, 1-4 cm in diameter, black and shiny, excipulum dark brown; asci cylindric-clavate, 150-200 x 9-10 μ m, pore blued by iodine, 8-spored; ascospores of two kinds, usually the upper four larger, 11-15 x 6-7 μ m, somewhat reniform, with ends narrowed, dark and opaque, the lower four smaller, 7-9 x 4-5 μ m, shape similar, usually more elliptical, hyaline, both types containing one to several oil drops; paraphyses slender, 1 μ m in diameter.

On decaying wood, usually Quercus species; fall (August-December).

Not common.

Distribution (Figure 55)

Iowa: RDJ 1975; Johnson: UI 1902, 1933; Lee: ISU 1970; Marion: UI 1939; Winneshiek: UI 1903.

It appears that many of the common stipitate Discomycetes can be found in relatively undisturbed, forested sites throughout Iowa. As indicated by the distribution maps, they are found in more counties and have a greater species diversity in the eastern one-third of Iowa. Approximately four times more forested land, a wider variety of tree species (Thornton and Morgan, 1959) and approximately fourteen percent more precipitation (Figure

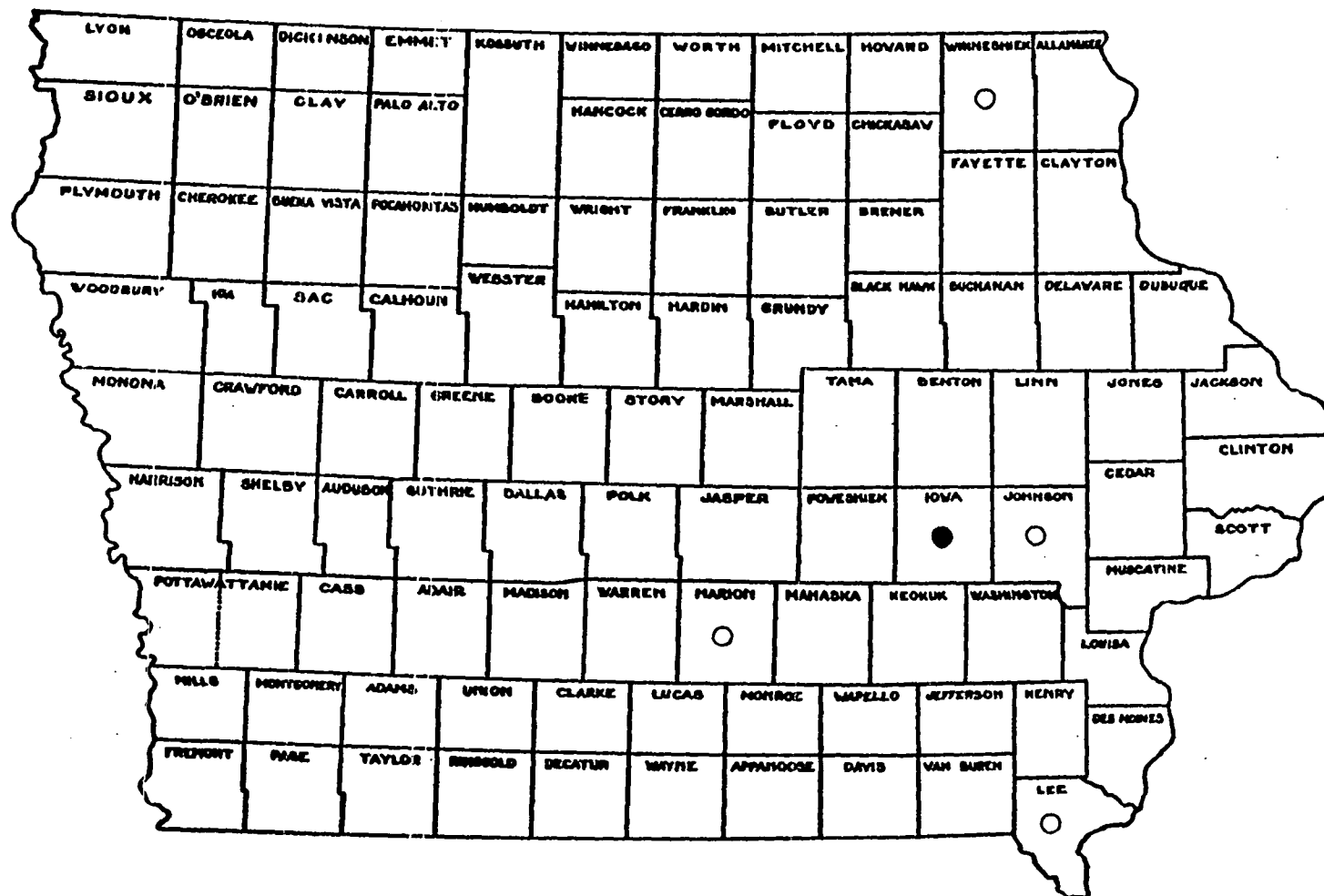


Figure 55. Distribution of *Phaeobulgaria inquinans* (Pers.) Nannf. in Iowa

56; Oschwald et al., 1965) in the eastern one-third of Iowa, as compared to the western one-third of Iowa, probably accounts for most of the diversity and abundance.

Most of the Iowa stipitate Discomycetes are seasonal in occurrence. The production of the apothecia lasts from a month or less in some genera and species (e.g., Morchella spp.) to two to three months in others (e.g., Helotium spp., Helvella spp.). Generally speaking, species with large conspicuous apothecia occur in the spring for a relatively short period of time; those with small apothecia occur in the summer and/or fall usually for a period of several months.

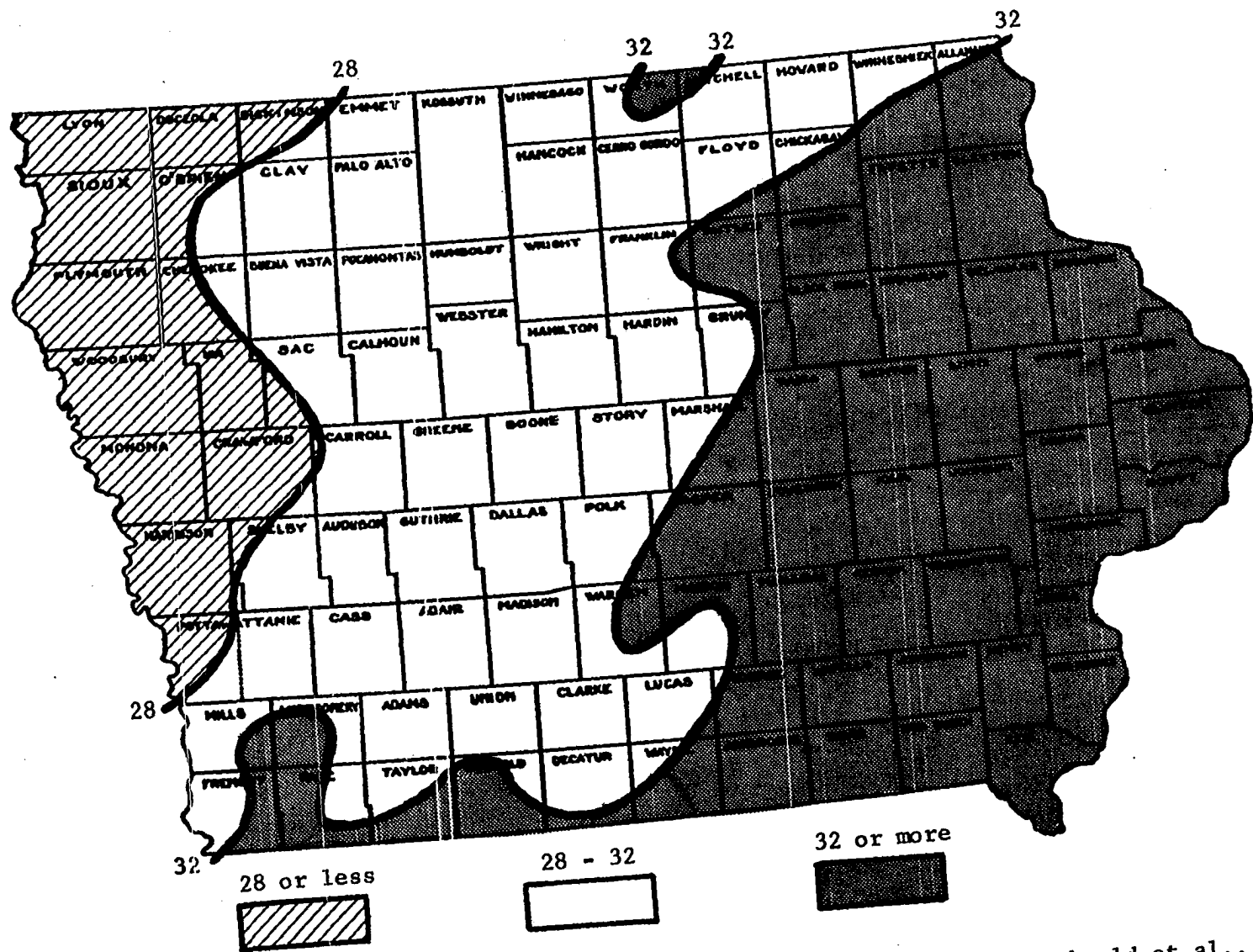


Figure 56. Average annual Iowa precipitation (in inches) (adapted from Oschwald et al., 1965)

PART III

LITERATURE REVIEW

Morels (Morchella spp.), at least the occurrence and collection of them, have been noted in the literature for nearly a century. Attempts to produce the ascocarps in culture date back nearly as far. Boyer (1891) reported he obtained two large morel ascocarps six weeks after he inoculated a soil mixture with old decaying ascocarps of morels. In 1905, Molliard (Constantin, 1936) obtained two ascocarps of morels from a mixture of soil and nonfermented apple pulp which had been put in pots and inoculated with mycelial cultures grown from ascospores of morels. The inoculated pots were kept in a cold room in the laboratory for six months and then placed outside in a garden for five months before morel ascocarps were produced. Molliard obtained the imperfect stage of Morchella, Constantinella, on nonfermented apple pulp approximately three weeks after inoculation with morel mycelium. There was no indication in either experiment that the substrates had been sterilized and/or that sterile conditions had been maintained.

Baker and Matkin (1959) reported ascocarps of morels were produced for a six week period in raised greenhouse beds of Cymbidium orchids. The beds, located in California, had been prepared six to eight months earlier using ground bark of white fir (Abies concolor) which also contained some wood fragments. This material was obtained from a burned forest area in California. Dolomite lime was added and the bark was fumigated with gaseous methyl bromide prior to planting. After planting, the beds were fertilized at one to two week intervals with ammonium nitrate and potassium chloride. The appearance of the morels in the beds was approximately two

months earlier than their normal occurrence in that part of California. Approximately three years elapsed between the occurrence of the morels and the publication of the report of their occurrence. During that period, no more morels appeared in the beds or similar beds. The occurrence of the morels was not explained. It was hypothesized that morel ascospores might have been carried with the bark from the burned area.

Discomycetes, including morels, have been commonly reported in burned areas (Sturgis, 1905; Krieger, 1967; Petersen, 1970). Sturgis found morels occurring abundantly in a burned area of a steep mountainside. Aspen, small spruce and other vegetation had been destroyed by fire approximately one year earlier. At the time the morels were found, no green vegetation had been reestablished in the area.

Many studies have been conducted on the growth of Morchella spp. mycelium in submerged or liquid culture. Brock (1951) studied the nutrition of Morchella esculenta utilizing various carbon and nitrogen sources. He found that M. esculenta grew well on media containing starch, maltose, d(-) fructose, d(+) turanose, d(+) glucose, and sucrose. Favorable nitrogen sources were l-cysteine-HCl, dl-aspartic acid, l(+) asparagine, urea, sodium nitrite, and various ammonium salts.

Robbins and Hervey (1959) reported that water extracts of beech wood increased the growth of Morchella in liquid culture. They had obtained similar results with Basidiomycetes using wood, tomato, and malt extracts.

Gilbert (1960) grew nine Morchella species and several strains of these species in submerged culture. In addition to the synthetic and natural substrates previously reported, Gilbert reported that other natural sources of nitrogen could be used as substrates for the production of

Morchella mycelium. These substrates were albumin, cottonseed meal, peanut meal, coconut meal, soybean meal, and wheat bran. In submerged culture, using a standard medium, Gilbert was able to distinguish species and strains on the basis of rate of growth, habit of growth, development of discrete mycelial spheres, color of spheres, flavor of mycelium, intensity of flavor, color of the supernatant liquor, and odor of the effluent air.

Litchfield et al. (1963) investigated the growth of three species of Morchella in a corn-steep liquor containing either glucose, maltose, or lactose. The results were similar to those of Brock. Differences among species in utilization of the carbon sources were noted. Litchfield (1967) has reviewed the literature from the period 1953-1966 concerning mycelial growth in submerged or liquid culture. He briefly discusses substrates, nutrients, temperature, pH, agitation, aeration, yield, nutrition, flavor, and economics primarily in relation to the commercial production of morel mycelium.

MATERIALS AND METHODS

Several aspects of the growth of Morchella esculenta in the field were investigated. These were soil analyses and vegetational studies of sites where M. esculenta occurred and mycorrhizal studies in the laboratory.

Mycorrhizal Studies

Several laboratory experiments were conducted to establish whether M. esculenta was mycorrhizal with Ulmus americana L. (American elm) and/or Acer saccharinum L. (silver maple). These were two of several tree species under which morels have been found growing abundantly.

In the first experiment, soil was obtained from a site where ascocarps of M. esculenta had been collected previously and transported to the laboratory where one gallon jars were filled approximately half full of soil and then sterilized. Sterile four-week old tree seedlings of U. americana were aseptically planted in the jars. The soil in each jar, except for the control jars, was inoculated with M. esculenta mycelium at the time the seedlings were transplanted. The jars were maintained in a growth chamber. The above procedure has been presented in detail by Howe (1964) who devised the method for studying mycorrhizae in white oak (Quercus alba L.).

In the above experiment, the tree seedlings were enclosed within the jars. A similar experiment, using both A. saccharinum and U. americana seedlings, was conducted in which the majority of the above ground (foliar) portion of the seedling extended through an opening in the rubber stopper used to close each jar. Cotton was packed around the stem of each seedling to prevent contamination of the soil and inoculum in the jars. The jars with the tree seedlings were maintained in a growth chamber as before.

Another study was conducted using Terra-Lite, moistened with half strength Hoagland's nutrient solution and a 0.5 percent dextrose solution, as the substrate instead of soil. The method used was similar to one used successfully by Hacskeylo (1953) to synthesize ectotrophic mycorrhizae in seedlings of Pinus virginiana Mill. Since pine seedlings grow relatively slowly, Hacskeylo was able to grow the pine seedlings for four months in two-liter flasks. In this study, because of the rapid growth of the A. saccharinum seedlings, the foliar part of the seedlings was not enclosed in the flask but extended through an opening in the rubber stopper as in the previous experiment. One seedling died approximately two months after the substrate was inoculated. The remainder of the experiment was terminated after approximately five months.

Soil Studies

Soil samples were taken at various sites in Iowa where ascocarps of M. esculenta were present. A soil sampler (Oakfield Apparatus, Inc.) was used to take 1½" diameter soil cores which were divided into samples. Thirteen sites were sampled in 1974 (Table 2). Six of the same sites, denoted in Table 2, were sampled in 1975. The 1974 samples were taken only in areas where ascocarps of M. esculenta were present. The 1975 samples were taken where ascocarps of M. esculenta were present, usually in or near the original sampling sites of 1974; also an equal number of soil samples were taken in adjacent areas (25-50 feet away) where no ascocarps of M. esculenta were developed. Each soil core was divided into two or three of the following: top one inch, A1 and/or A2 horizons. Each of these layers was placed in a separate plastic bag, labeled and tied to prevent

Table 2. Location of sites used for soil and vegetation studies

Site number	County	Township name	Township location	Site
1 ^a	Fremont	Washington	T-68N R-42W	Waubonsie State Park
2 ^a	Fremont	Washington	T-68N R-42W	Waubonsie State Park
3 ^a	Pottawattamie	Hazel Dell	T-76N R-43W	Section 36, private woods
4	Guthrie	Dodge	T-81N R-31W	Section 31, private woods
5 ^a	Webster	Otho	T-88N R-28W	Dolliver Memorial State Park
6 ^a	Boone	Cass	T-82N R-26W	4-H Camp
7	Boone	Worth	T-83N R-26W	Ledges State Park
8 ^a	Boone	Yell	T-84N R-27W	Holst State Forest
9 ^a	Boone	Yell	T-84N R-27W	Holst State Forest
10	Story	Milford	T-84N R-23W	Section 6, private woods
11	Story	Milford	T-84N R-23W	Section 6, private woods
12	Dubuque	Liberty	T-90N R-2W	White Pine Hollow State Preserve
13	Allamakee	Creek	T-97N R-4W	Yellow River State Forest

^aDenotes 1975 sites sampled both years (1974 and 1975).

moisture loss. Soil temperatures at 1, 3, and 6 inch depths were recorded for each site. In the laboratory, the soil samples were analyzed for the following: available nitrate-nitrogen, available phosphorus, available potassium, exchangeable divalent cations (primarily magnesium and calcium), organic matter, pH, texture, and water content. The procedures for the soil analyses, sources, and any modifications of the procedures are listed.

Available nitrate-nitrogen was determined by a combination of two methods: (1) the nitrate-nitrogen production method as adapted for research laboratory use (Stanford and Hanway, 1955) and (2) the nitrate-nitrogen selective electrode method (Bremner et al., 1968). The following modifications were made: the initial leachate and the second leachate (taken after an interval of seven days instead of fourteen days) were obtained using the nitrate-nitrogen method. Each leachate was filtered before determining the nitrate-nitrogen with a nitrogen selective electrode (Orion Research Corporation).

Available phosphorus was determined by the dilute hydrochloric acid-ammonium fluoride method (Olsen and Dean, 1965). Available potassium was determined by the flame photometer method (Pratt, 1965). The method was modified as follows: a two gram soil sample was placed in a test tube, 10 ml of neutral 1N ammonium acetate was added to the sample, the mixture was shaken for three minutes, and filtered; then the filtrate was tested in the flame photometer.

Exchangeable divalent cations were determined by a combination of two methods: (1) a soil extract was made according to Chapman (1965) with the following modification--the soil was stirred every three to five minutes during a thirty minute period, then filtered immediately rather than fil-

tering after the soil mixture had stood overnight; (2) the filtrate was tested according to Heald (1965) with the following modification: chelating agents for ions other than magnesium and calcium were omitted from the procedure.

Organic matter content was determined by a wet combustion process which incorporates the use of a photoelectric colorimeter (Graham, 1948). The method was modified as follows: the potassium dichromate-sulfuric acid-soil mixture was allowed to stand for seven days before the supernatant was withdrawn for testing.

Hydrogen ion concentration (pH) was determined by the glass electrode method (Peech, 1965). The following modification was used: 0.01 M CaCl_2 solution was used in place of distilled water.

Texture was determined by the pipette method (Kilmer and Alexander, 1949).

Water content was determined by gravimetric method (Gardner, 1965).

Vegetational Studies

The vascular plant flora of each site was recorded at the time field collections of soil samples were made in the spring. Much of the vegetation was not flowering at the time ascocarps of M. esculenta were present, and these plants could not always be identified to species.

RESULTS AND DISCUSSION

Mycorrhizal Studies

All of the attempts to demonstrate the presence or absence of a mycorrhizal association between M. esculenta and U. americana or A. saccharinum were either unsuccessful or no definite conclusions could be made. The experiments are reported here primarily to establish that certain methods are not favorable, at least with this particular fungus, for mycorrhizal studies.

The first experiment failed to demonstrate the presence or absence of mycorrhizae as the tree seedlings died approximately two weeks after inoculation. The foliar parts of the U. americana seedlings in inoculated soil jars became covered with a fuzzy, whitish mycelium. A similar fungus was present on the surface of the soil in the jars.

The dead trees were placed on sterile culture media to isolate and identify the whitish mycelium. Cultures from three of the four trees were Morchella mycelium or appeared to Morchella mycelium. Fusarium cultures also were obtained from one of these three trees. Only Fusarium was isolated from the fourth tree.

The second experiment, similar to the first except that the foliar part of each tree seedling extended through an opening in the rubber stopper, also failed to demonstrate the presence or absence of mycorrhizae. The seedlings did not grow much and most of them died four to six weeks after the soil was inoculated. The seedlings had little new root growth and no mycorrhizae. No Morchella mycelium could be recovered from the soil in isolation attempts. Contamination of the soil in the jars was

much greater than in the previous experiment. The following fungal contaminants were isolated: Alternaria, Aspergillus, Cephalosporium, Fusarium, Penicillium, Pythium, Rhizopus, Stysanus, and Trichoderma.

In the third experiment, in which Terra-Lite was used as a substrate, the results were not conclusive. The one A. saccharinum seedling which died approximately two months after the substrate was inoculated was examined for mycorrhizae. None were present. Morchella mycelium, as well as Alternaria, was isolated from the inoculated substrate. No mycorrhizae were present on the seedlings which were allowed to grow for five months, and no Morchella mycelium could be isolated from the inoculated substrate. The following fungal contaminants were isolated: Alternaria, Epicoccum, and Sphaeropsis. Bacteria and other fungal contaminants were isolated from the control flasks.

It has been suggested that Morchella species may form facultative mycorrhizae in which the mycelium is concentrated around, not in, the rootlets of trees. This type is sometimes referred to as peritrophic mycorrhizae (Singer, 1961). Singer (1961) states that Morchella species are frequently found in the vicinity of Ulmus, rosaceous fruit trees, Carpinus and Fraxinus. I have found M. esculenta commonly occurring within the drip-line of U. americana but usually the tree is dead or nearly dead. Finding Morchella species around dead trees of U. americana would suggest that M. esculenta is not mycorrhizal. Perhaps the presence of Morchella species around dead or dying trees of U. americana could be explained, at least in part, by the fact that Morchella has been shown to be capable, in pure culture conditions, of causing soft rot decay (Duncan and Eslyn, 1966).

Soil Studies

The data from the soil studies are presented in Tables 3-16. The numbers (1-13) at the top of each table refer to the sites where soil samples were taken. The terms "in" and "out", used as column headings in some tables, refer to soil samples taken in areas where ascocarps of M. esculenta were present (in) or areas where they were not present (out). In Table 2, the sites are listed and designated by number and are in geographical order. The most western and/or southern sites are listed first; the most eastern and/or northern sites are listed last.

The top one inch, A1, and A2 horizons were analyzed for various physical and chemical factors. The top one inch included the O and part of the A1 horizon. The O horizon, consisting of fresh and partly decomposed organic matter, occurs most commonly in undisturbed forested areas. It seldom occurs in grassland soils and is destroyed by disturbance such as grazing and plowing. The A1 and A2 horizons, usually present in most forested soil profiles, are the most active biologically. The dark color of A horizons is due to the well decomposed organic matter which coats the mineral particles in this horizon. The A horizons of Iowa soils range from two to twenty-four inches in thickness (Oschwald et al., 1965).

Soil texture (Table 13) influences the productivity of soil. Sandy soils, having a high proportion of coarse particles, lack the water and nutrient holding capacity for good plant growth. Soils with a high proportion of fine particles (high clay soils) are usually not highly productive because too much water is retained which retards good root development. The soils in this study did not have high proportions of coarse or fine particles. Most of the soils were loam or silt loam which are usually the

most productive soils in Iowa (Oschwald et al., 1965).

The water content of the soils is presented in Table 14. Fungi, like other plants, absorb their food in solution. This, combined with the fact that fleshy fungi are often 85-90 percent water (Groves, 1962), indicates that a supply of water is essential for the growth and reproduction of fungi. The minimal, optimal, and/or maximal water contents of soils necessary for the growth and reproduction of Morchella cannot be determined from the data.

It appears that soil temperatures may have an effect on the production of Morchella ascocarps. The temperatures recorded in this study are similar to the temperatures at which Gilbert (1960) obtained the maximum or optimal growth of Morchella mycelium in submerged culture. The rapid, seemingly overnight, appearance of Morchella ascocarps in the spring, would appear to necessitate maximum or optimal mycelial growth. How temperature causes or affects this growth is not known. Hawker (1966) states that temperature does affect reproduction, but that its effects can seldom be separated from those of other environmental factors.

The pH (6.9) reported by Brock (1951) as producing optimum growth of Morchella mycelium in liquid culture was similar to the pH of the soils in this study (Tables 11, 12). Other fungi have similar optimal pH as most fungi grow well on an acid or slightly acid substrate.

The data concerning levels of essential soil nutrients (Tables 3-10) do not suggest any distinctive differences between sites where ascocarps of Morchella are and are not present. The data indicate that Morchella ascocarps grow in a wide range of nutrient levels. The nutrients C (organic matter), N, P, K, Ca, and Mg are necessary to the growth of most fungi.

Table 3. Available nitrate-nitrogen in ppm in soil samples from Morchella sites; 1974

Layer	1 ^a	2	3	4	5	6	7	8	9	10	11	12	13
Top-1 ^b	18.0	12.3	--	9.4	5.6	3.6	6.8	3.5	6.5	4.1	5.6	5.0	8.0
Top-2	45.0	36.0	--	48.0	23.7	38.3	56.3	48.7	64.3	42.0	41.3	35.8	15.0
A1-1	7.5	8.0	9.8	4.6	5.8	4.9	5.5	3.1	5.5	2.9	4.9	4.5	5.7
A1-2	21.0	19.3	49.3	44.0	26.0	24.3	38.0	34.0	44.0	24.5	19.8	16.3	14.5
A2-1	--	--	7.8	3.1	3.3	--	3.3	2.8	3.8	2.7	--	2.5	--
A2-2	--	--	25.8	12.3	35.5	--	19.8	17.8	29.0	10.8	--	2.2	--

^aNumbers 1-13 refer to the sites listed in Table 2. This also applies to Tables 4-16.

^bTop-1, Top-2, etc. indicate top one inch, first and second leachates, respectively.

Table 4. Available nitrate-nitrogen in ppm in soil samples from and near Morchella sites; 1975

Layer	1		2		3		6		8		9	
	in ^a	out ^b	in	out	in	out	in	out	in	out	in	out
Top-1	2.5	2.5	1.9	1.7	2.3	1.6	1.1	1.0	1.2	1.7	1.2	1.0
Top-2	8.9	8.1	6.3	8.4	8.2	7.9	8.2	10.3	9.9	9.4	7.6	6.8
A1-1	1.6	1.3	1.2	0.9	1.5	0.9	0.8	0.9	0.8	1.0	0.9	0.9
A1-2	6.8	4.5	3.3	5.0	5.9	4.7	0.7	6.7	5.5	4.8	3.6	6.2

^aSoil sample taken where ascocarps of M. esculenta were present.

^bSoil sample taken where ascocarps of M. esculenta were not present.

Table 5. Available phosphorus in ppm in soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Top	31.5	82.6	--	24.5	23.8	21.1	15.1	20.8	17.2	11.9	14.4	13.3	29.2
A1	36.1	34.3	8.4	29.8	23.8	16.8	10.2	20.8	15.1	6.3	15.1	8.8	28.4
A2	--	--	12.3	29.8	27.8	--	11.5	32.2	11.7	7.2	--	8.1	--

Table 6. Available phosphorus in ppm in soil samples from and near Morchella sites; 1975

Layer	¹ in ^a out ^b		² in out		³ in out		⁶ in out		⁸ in out		⁹ in out	
Top	88.4	116.3	276.0	437.5	64.8	70.0	117.3	63.0	138.3	173.3	269.5	154.0
A1	138.3	183.75	252.0	472.5	34.8	39.9	91.0	269.5	189.0	98.0	59.5	43.8

^aSoil sample taken where ascocarps of M. esculenta were present.

^bSoil sample taken where ascocarps of M. esculenta were not present.

Table 7. Available potassium in ppm in soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Top	395.0	272.0	---	382.3	360.0	215.0	322.5	435.5	217.5	207.5	117.5	242.5	200.0
A1	277.5	240.0	282.5	267.5	395.0	127.5	230.0	382.5	167.5	157.5	80.0	175.0	167.5
A2	---	---	322.5	207.5	337.5	---	195.0	355.0	142.5	87.5	---	125.0	---

Table 8. Available potassium in ppm in soil samples from and near Morchella sites; 1975

Layer	1		2		3		6		8		9	
	in ^a	out ^b	in	out	in	out	in	out	in	out	in	out
Top	457.5	285.0	382.5	380.0	440.0	397.5	212.5	197.5	270.0	235.0	260.0	187.5
A1	377.5	420.0	440.0	332.5	265.0	340.0	172.5	152.5	155.5	160.0	175.0	152.5

^aSoil sample taken where ascocarps of M. esculenta were present.

^bSoil sample taken where ascocarps of M. esculenta were not present.

Table 9. Exchangeable divalent cations in meq/100g in soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Top	50.2	42.1	--	41.8	35.0	31.6	34.7	28.3	45.4	23.2	28.1	45.3	27.5
A1	23.9	26.9	26.4	28.9	22.7	19.7	21.9	17.8	28.0	14.0	17.9	21.9	20.1
A2	--	--	21.5	18.1	15.7	--	16.5	11.9	22.7	9.3	--	8.7	--

Table 10. Percent organic matter in soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Top	14.0	13.8	--	14.2	13.9	9.4	11.9	12.6	14.2	10.1	10.8	14.3	10.8
A1	5.4	6.2	6.5	7.3	7.1	3.5	6.3	6.1	7.1	4.6	6.4	7.2	6.1
A2	--	--	3.7	3.3	3.5	--	3.3	4.0	6.0	0.8	--	1.9	--

Table 11. Hydrogen ion concentration (pH) of soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Top	6.6	6.5	---	6.4	6.4	7.1	6.5	6.5	6.7	6.4	6.5	6.3	6.6
A1	6.5	6.4	6.2	6.4	6.3	7.0	6.5	6.5	6.7	6.4	6.3	6.2	6.7
A2	---	---	6.2	6.2	6.2	---	6.4	6.3	6.7	5.9	---	5.7	---

Table 12. Hydrogen ion concentration (pH) of soil samples from and near Morchella sites; 1975

Layer	1		2		3		6		8		9	
	in ^a	out ^b	in	out	in	out	in	out	in	out	in	out
Top	6.7	6.7	6.2	6.4	6.0	6.3	6.1	6.4	6.2	6.4	5.9	6.1
A1	6.8	6.9	6.3	5.7	6.4	6.4	6.6	6.7	6.2	6.4	5.8	6.3

^aSoil sample taken where ascocarps, M. esculenta, were present.

^bSoil sample taken where ascocarps, M. esculenta, were not present.

Table 13. Percent sand, silt, and clay in soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13 ^a
A1 sand	4.8	3.7	1.6	3.3	56.4	62.5	41.9	50.4	42.7	51.4	49.1	4.2	--
silt	76.6	77.7	73.2	73.8	29.0	23.7	35.4	36.4	37.1	33.9	36.6	89.5	--
clay	18.6	18.6	25.2	23.0	14.5	13.7	22.6	13.3	20.2	14.7	14.4	6.3	--
	silt, loam ^b	silt, loam	silt, loam	silt, loam	sandy loam	sandy loam	loam	loam	loam	loam	loam	silt	--
A2 sand	--	--	1.6	1.9	60.3	--	43.4	52.6	45.4	50.9	--	3.2	--
silt	--	--	72.2	73.3	26.9	--	33.6	33.8	33.1	32.2	--	84.2	--
clay	--	--	26.2	24.9	12.8	--	23.1	13.6	21.4	16.8	--	12.6	--
	--	--	silt, loam	silt, loam	sandy loam	sandy loam	loam	loam	loam	loam	loam	silt	--

^aData for this site were lost.

^bU.S.D.A. soil texture names.

Table 14. Percent water content of soil samples from Morchella sites; 1974

Layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Top	58.9	59.2	--	42.2	46.8	29.5	35.8	37.3	50.4	36.5	46.2	76.2	41.8
A1	36.1	39.2	25.4	36.6	35.8	18.0	26.3	24.8	37.1	25.8	34.2	50.8	34.7
A2	--	--	24.8	28.9	26.6	--	20.9	20.3	30.6	20.6	--	26.9	--

Table 15. Soil temperatures °C at 1, 3, and 6 inch depths in Morchella sites; 1974

Depth	1	2	3	4	5 ^a	6	7	8	9	10	11	12	13
1 inch	14.0	13.0	14.5	15.0	--	12.5	11.0	16.0	14.0	14.0	12.5	13.0	12.5
3 inches	12.0	12.0	13.0	13.5	--	11.0	10.0	14.0	12.5	13.5	12.0	12.0	12.0
6 inches	12.5	12.0	13.0	12.5	--	12.5	9.5	11.5	10.5	12.0	11.5	11.5	11.5

^aTemperature not taken.

Table 16. Soil temperatures °C at 1, 3, and 6 inch depths in Morchella sites; 1975

Depth	1	2	3	6	8	9
1 inch	19.0	16.5	15.0	13.5	16.0	16.0
3 inches	18.5	16.0	14.0	12.0	13.0	15.0
6 inches	15.0	15.0	14.0	11.5	12.0	13.0

Brock (1951), Robbins and Hervey (1959), and others have evaluated various inorganic and organic nutrients in relation to the growth of Morchella mycelium in culture. Their studies indicate that Morchella can utilize a variety of nutrient sources. These studies usually did not indicate the minimal and maximal levels necessary for the optimum growth of the mycelium. Morton (1967) states that "reproduction is often induced when some external or internal factor, frequently some nutrient, becomes limiting for vegetative development". The wide range of nutrient levels recorded in this study would tend to indicate that these nutrients are not a primary factor in the induction of ascocarp production in Morchella.

Vegetational Studies

The vascular plants associated with sites where ascocarps of M. esculenta were present in 1974 and 1975 are listed in Table 17. The plants were classed as either woody associates or herbaceous associates. Generally the same species of plants were present in the sites where ascocarps of M. esculenta were not developed. The plant noticeably absent from the sites lacking Morchella ascocarps was U. americana. This plant distribution would support the suggestion that there may be a tree-fungus association between U. americana and M. esculenta. My experience of finding Morchella species associated with other tree species (Acer saccharinum, Juniperus virginiana, Tilia americana) and dead trees of U. americana would suggest otherwise. If Morchella forms associations with trees, it appears it must form them with several species of trees.

Ulmus americana was the only woody plant associate present in all

Table 17. Vascular plant associates of Morchella esculenta

Site number	Woody associates	Herbaceous associates
1	<u>Rhus radicans</u> <u>Ulmus americana</u> (dying)	<u>Arisaema triphyllum</u> <u>Cystopteris</u> sp. <u>Dicentra cucullaria</u> <u>Impatiens</u> sp. <u>Osmorhiza</u> sp.
2	<u>Asimina triloba</u> <u>Parthenocissus quinquefolia</u> <u>Ulmus americana</u> (dead)	<u>Arisaema triphyllum</u> <u>Dicentra cucullaria</u> <u>Galium</u> sp. <u>Impatiens</u> sp. <u>Viola</u> sp.
3	<u>Celtis occidentalis</u> <u>Cornus</u> sp. <u>Morus</u> sp. <u>Rhus radicans</u> <u>Ribes</u> sp. <u>Rubus</u> sp. <u>Symphoricarpos</u> sp. <u>Ulmus americana</u> (dead)	<u>Carex</u> sp. <u>Osmorhiza</u> sp. <u>Viola</u> sp.
4	<u>Carya</u> sp. <u>Cornus</u> sp. <u>Fraxinus</u> sp. <u>Juglans</u> sp. <u>Juniperus virginiana</u> <u>Quercus</u> sp. <u>Ribes</u> sp. <u>Rosa</u> sp. <u>Ulmus americana</u> (dead) <u>Ulmus</u> sp.	<u>Botrychium virginianum</u> <u>Carex</u> sp. <u>Galium</u> sp. <u>Helianthus</u> sp. <u>Phlox divaricata</u> <u>Viola</u> sp.
5	<u>Acer nigra</u> <u>Corylus americana</u> <u>Fraxinus</u> sp. <u>Ostrya americana</u> <u>Ribes</u> sp. <u>Rubus</u> sp. <u>Smilax</u> sp. <u>Ulmus americana</u> <u>Ulmus americana</u> (dead)	<u>Adiantum pedatum</u> <u>Galium aparine</u> <u>Galium</u> sp. <u>Hydrophyllum</u> sp. <u>Isopyrum biternatum</u> <u>Laportia</u> sp. <u>Mitella diphylla</u> <u>Osmorhiza</u> sp. <u>Phlox divaricata</u>

Table 17. (Continued)

Site number	Woody associates	Herbaceous associates
6	<u>Acer nigra</u> <u>Fraxinus</u> sp. <u>Ostrya virginiana</u> <u>Parthenocissus quinquefolia</u> <u>Ribes</u> sp. <u>Tilia americana</u> <u>Ulmus americana</u> (dead)	<u>Carex</u> sp. <u>Dicentra cucullaria</u> <u>Galium aparine</u> <u>Galium</u> sp. <u>Hepatica acutiloba</u> <u>Hydrophyllum</u> sp. <u>Phlox divaricata</u> <u>Poa</u> sp. <u>Polygonatum</u> sp. <u>Sanguinaria canadensis</u> <u>Smilacina</u> sp.
7	<u>Ostrya virginiana</u> <u>Parthenocissus quinquefolia</u> <u>Prunus virginiana</u> <u>Quercus</u> sp. <u>Ribes</u> sp. <u>Tilia americana</u> <u>Ulmus americana</u> <u>Ulmus americana</u> (dead)	<u>Aquilegia canadensis</u> <u>Carex</u> sp. <u>Dicentra cucullaria</u> <u>Galium</u> sp. <u>Isopyrum biternatum</u> <u>Phlox divaricata</u> <u>Solidago</u> sp. <u>Uvularia</u> sp. <u>Viola</u> sp.
8	<u>Acer nigra</u> <u>Juglans</u> sp. <u>Parthenocissus quinquefolia</u> <u>Quercus</u> sp. <u>Ribes</u> sp. <u>Staphylea trifolia</u> <u>Tilia americana</u> <u>Ulmus americana</u> (dead)	<u>Bromus</u> sp. <u>Cystopteris</u> sp. <u>Galium aparine</u> <u>Helianthus</u> sp. <u>Isopyrum biternatum</u> <u>Phlox divaricata</u> <u>Poa</u> sp. <u>Ranunculus abortivus</u> <u>Sanguinaria canadensis</u> <u>Thalictrum</u> sp. <u>Viola</u> sp.
9	<u>Acer saccharum</u> <u>Carya</u> sp. <u>Juglans</u> sp. <u>Quercus</u> sp. <u>Ulmus americana</u> (dead)	<u>Actea</u> sp. <u>Asarum canadense</u> <u>Botrychium virginianum</u> <u>Dicentra cucullaria</u> <u>Erythronium albidum</u> <u>Geranium</u> sp. <u>Impatiens</u> sp. <u>Laportia canadensis</u> <u>Mitella diphylla</u> <u>Osmorhiza</u> sp.

Table 17. (Continued)

Site number	Woody associates	Herbaceous associates
		<u>Phlox divaricata</u> <u>Sanguinaria canadensis</u> <u>Sanicula</u> sp. <u>Thalictrum</u> sp.
10	<u>Acer nigra</u> <u>Carya</u> sp. <u>Ostrya americana</u> <u>Quercus</u> sp. <u>Ribes</u> sp. <u>Smilax</u> sp. <u>Tilia americana</u>	<u>Aquilegia canadensis</u> <u>Carex</u> sp. <u>Claytonia virginica</u> <u>Dicentra cucullaria</u> <u>Galium</u> sp. <u>Hepatica acutiloba</u> <u>Hydrophyllum</u> sp. <u>Laportia canadensis</u> <u>Osmorhiza</u> sp. <u>Phlox divaricata</u> <u>Polygonatum</u> sp. <u>Ranunculus abortivus</u> <u>Sanguinaria canadensis</u> <u>Viola pennsylvanica</u>
11	<u>Acer nigra</u> <u>Juniperus virginiana</u> <u>Ostrya americana</u> <u>Parthenocissus quinquefolia</u> <u>Ribes</u> sp. <u>Rubus</u> sp. <u>Tilia americana</u> <u>Ulmus americana</u> (dead) <u>Xanthoxylum americanum</u>	<u>Carex</u> sp. <u>Galium</u> sp. <u>Helianthus</u> sp. <u>Hydrophyllum</u> sp. <u>Laportia canadensis</u> <u>Polygonatum</u> sp. <u>Sanguinaria canadensis</u> <u>Viola pennsylvanica</u>
12	<u>Ulmus americana</u> <u>Ulmus americana</u> (dead)	<u>Arisaema triphyllum</u> <u>Geranium</u> sp. <u>Hydrophyllum</u> sp. <u>Osmorhiza</u> sp. <u>Urtica</u> sp.
13	<u>Fraxinus</u> sp. <u>Parthenocissus quinquefolia</u> <u>Populus</u> sp. <u>Ribes</u> sp. <u>Rubus</u> sp. <u>Smilax</u> sp. <u>Tilia americana</u> <u>Ulmus americana</u>	<u>Adiantum pedatum</u> <u>Arisaema triphyllum</u> <u>Athyrium</u> sp. <u>Botrychium virginianum</u> <u>Desmodium</u> sp. <u>Geranium</u> sp. <u>Orchis spectabilis</u> <u>Osmorhiza</u> sp.

Table 17. (Continued)

Site number	Woody associates	Herbaceous associates
	<u>Ulmus americana</u> (dead) <u>Vitis</u> sp.	<u>Sanguinaria canadensis</u> <u>Sanicula</u> sp. <u>Smilacina</u> sp. <u>Uvularia</u> sp.

sites where ascocarps of M. esculenta were present. Other woody associates present in six or more of the sites were Parthenocissus quinquefolia, Ribes sp., and Tilia americana. Herbaceous associates present in six or more sites were Galium sp., Osmorhiza sp., Phlox divaricata, Sanguinaria canadensis, and Viola spp.

The plants listed above are commonly encountered in forested sites throughout Iowa and, therefore, would not be considered good indicator species for M. esculenta.

PART IV

CONCLUSIONS

The stipitate discomycetes of Iowa are a diverse group of fungi in relation to size, shape, and color of the ascocarps, time of occurrence, and distribution within Iowa.

Thirty-two species were collected during this study and three of these (Helotium fraterum, Rutstroemia firma, Verpa bohemica) have not been previously reported as occurring in Iowa. Ten other species were represented by specimens in herbaria or teaching collections.

Many of the common stipitate Discomycetes can be found in relatively undisturbed, forested sites throughout Iowa. They are generally found in more counties and have a greater species diversity in the eastern one-third of Iowa. Factors probably significant in their distribution are more precipitation, a wider variety of tree species and more forested land in eastern Iowa.

Mycorrhizal studies, conducted in the laboratory, did not conclusively demonstrate the presence or absence of a mycorrhizal association between M. esculenta and U. americana or A. saccharinum. The inconclusive results could be attributed to contamination of the substrate and death of the tree seedlings soon after inoculation.

Soil from sites where ascocarps of M. esculenta were present were not notably different from soils of sites where ascocarps were not present. Ascocarps can develop in a range of soil nutrient levels and soil types. In laboratory studies, optimum growth of mycelium of Morchella was obtained at temperature and pH levels similar to those obtained in this study. No meaningful conclusions could be made concerning the influence of soil fac-

tors on ascocarp production.

Ulmus americana was the only vascular plant species present in all of the sites where ascocarps of M. esculenta were collected. Woody plants occurring in six or more ascocarp producing sites were Parthenocissus quinquefolia, Ribes sp., and Tilia americana. Herbaceous plants occurring in six or more of these sites were Galium sp., Osmorhiza sp., Phlox divaricata, Sanguinaria canadensis, and Viola species. No definitive evidence was obtained concerning an association of M. esculenta mycelium with roots of vascular plants.

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